THE

PHYSIOLOGICAL ANATOMY

AND

PHYSIOLOGY OF MAN.

BY

ROBERT BENTLEY TODD, M.D., F.R.S.,
FELLOW OF THE COLLEGE OF PHYSICIANS, AND PHYSICIAN TO KING'S COLLEGE HOSPITAL;

AND

WILLIAM BOWMAN, F.R.S.,
FELLOW OF THE COLLEGE OF SURGEONS, SURGEON TO KING'S COLLEGE HOSPITAL AND THE ROYAL LONDON OPHTHALMIC HOSPITAL;

LATE PROFESSORS OF PHYSIOLOGY AND GENERAL AND MORBID ANATOMY IN KING'S COLLEGE, LONDON.

COMPLETE IN ONE VOLUME.

WITH TWO HUNDRED AND NINETY-EIGHT ILLUSTRATIONS.

PHILADELPHIA:
BLANCHARD AND LEA.
1857.

TO

SIR BENJAMIN COLLINS BRODIE, BART.,

D.C.L, F.R.S., ETC. ETC.,

CORRESPONDING MEMBER OF THE INSTITUTE OF FRANCE,

SERGEANT SURGEON TO THE QUEEN,

WHOSE MIND,

EARLY TRAINED IN PHYSIOLOGICAL RESEARCHES,

HAS BEEN DEVOTED

THROUGH A LONG LIFE OF EMINENT USEFULNESS

TO THE PRACTICE AND IMPROVEMENT

OF THE HEALING ART,

This Work is Dedicated

BY

THE AUTHORS.

PREFACE.

The work, which is now brought to a conclusion, was commenced in the year 1843, having been designed as a text-book for the lectures on General Anatomy and Physiology, given in King's College, London.

In its title, we adopted the term *Physiological* Anatomy, in preference to the older one of *General*, or the later one of *Histological*, as being more comprehensive than either, and as denoting precisely that kind of anatomy, a knowledge of which is especially required for the investigation of those subjects which ought to come under consideration in a Physiological course.

We proposed to ourselves to give such a view of the main facts and doctrines of Anatomy and Physiology, particularly of those bearing on practical Medicine and Surgery, as might suffice for the wants of the student and practitioner. Following that great master, Haller, we were desirous of giving to Anatomy a greater degree of prominence than had been usual in Physiological works, under the conviction that a thorough training in its several branches, descriptive, physiological, and comparative, is necessary to the formation of those habits of mind which best fit their possessor for the successful investigation and the correct appreciation of physiological science. And we aimed at resting our anatomical descriptions, at least as regards the more important points, upon our own investigations, and

at repeating former experiments, or devising new ones, wheneve questions of sufficient interest presented themselves.

While we must humbly confess how small have been the advance attributable to our own labours, the immense extension given to th sciences of Anatomy and Physiology during the last fifteen years may be admitted as some explanation of the delay that has occurre in the publication of our work, a delay that has been a constant source of regret to us, since we began to discover how impossible it would be for us to complete it within the term originally contemplated. That, in spite of repeated procrastination, it should have been so favourably received, both at home and abroad, has been the greatest encouragement to us, and demands our most thankful acknowledgments. If, indeed, our pursuits had tended to no other end than the cultivation of science, this book might have been finished long ago; but the increasing interruptions incident to a professional life, and the large demand made on us by studies of a practical kind, began at an early period to impede our progress. These hindrances did not diminish as time wore on, nor were they lessened by the fact of the authorship being in the hands of two persons, however cordially united by common views and the ties of friendship, or by the necessity for frequent and prolonged conferences which that double authorship entailed.

Such is the apology we have to offer for the tardy completion of our work. It will, we doubt not, be fully appreciated by candid men who know by experience how multifarious are the calls made upon those who not only are candidates for professional employment in London, but hold also the responsible position of public teachers in a large School and Hospital.

Were it not, indeed, for the kind and valuable co-operation of Dr. Beale, who is now the sole occupant of the physiological chair in King's College, we should not even yet have been released from our

difficulties. Dr. Beale, knowing all our views, and having worked with us on many points, has given us very important assistance in drawing up the concluding chapters of the work. Our warmest thanks are due to our friend and colleague for the patient industry and admirable judgment, with which, stepping out of his proper path of independent investigation, he has carried out our intentions, and enabled us, although at the eleventh hour, to fulfil our engagement to our pupils and to the public.

To our friend Dr. H. Hyde Salter we are indebted for several excellent drawings, as well as for other valuable assistance.

We desire also to express our thanks to Mr. Vasey for the skill and ability with which he has executed his portion of the task, that of engraving the drawings on wood.

W. B. —— R. B. T.

LONDON, *December* 1, 1856.

CONTENTS.

INTRODUCTION.

CHAPTER I.

OF THE CONSTITUENTS OF ANIMAL BODIES.—THE TISSUES AND THEIR PROPERTIES.

CHAPTER II.

OF THE MINUTE MOVEMENTS OCCURRING IN THE BODY.

CHAPTER III.

OF LOCOMOTION.—ITS PASSIVE ORGANS.

CHAPTER IV.

PASSIVE ORGANS OF LOCOMOTION, CONTINUED.

CHAPTER V.

PASSIVE ORGANS OF LOCOMOTION, CONTINUED.

CHAPTER VI.

PASSIVE ORGANS OF LOCOMOTION, CONTINUED.

CHAPTER VII.

ACTIVE ORGANS OF LOCOMOTION.

CHAPTER VIII.

INNERVATION.

CHAPTER IX.

INNERVATION, CONTINUED.

CHAPTER X.

INNERVATION, CONTINUED.

CHAPTER XI.

INNERVATION, CONTINUED.

CHAPTER XII.

INNERVATION, CONTINUED.

CHAPTER XIII.

INNERVATION, CONTINUED.

CHAPTER XIV.

INNERVATION, CONTINUED.

CHAPTER XV.

INNERVATION, CONTINUED.

CHAPTER XVI.

INNERVATION, CONTINUED.

CHAPTER XVII.

INNERVATION, CONTINUED.

CHAPTER XVIII.

INNERVATION, CONTINUED.

CHAPTER XIX.

INNERVATION, CONTINUED.

CHAPTER XX.

INNERVATION, CONTINUED.

CHAPTER XXI.

INNERVATION, CONTINUED.

CHAPTER XXII.

DIGESTION.

CHAPTER XXIII.

DIGESTION, CONTINUED.

CHAPTER XXIV.

DIGESTION, CONTINUED.

CHAPTER XXV.

DIGESTION, CONTINUED.

CHAPTER XXVI.

ABSORPTION.

CHAPTER XXVII.

THE BLOOD.

CHAPTER XXVIII.

THE CIRCULATION OF THE BLOOD.

CHAPTER XXIX.

RESPIRATION.

CHAPTER XXX.

ANIMAL HEAT.

CHAPTER XXXI.

VOICE.

CHAPTER XXXII.

SECRETION.

CHAPTER XXXIII.

SECRETING GLANDS.

CHAPTER XXXIV.

SECRETING GLANDS, CONTINUED.

CHAPTER XXXV.

DUCTLESS GLANDS.

CHAPTER XXXVI.

GENERATION.

CHAPTER XXXVII.

GENERATION, CONTINUED.

CHAPTER XXXVIII.

GENERATION, CONTINUED.

CHAPTER XXXIX.

GENERATION, CONTINUED.

CHAPTER XL.

GENERATION, CONTINUED.

CHAPTER XLI.

DEVELOPMENT.

CHAPTER XLII.

DEVELOPMENT, CONTINUED.

CHAPTER XLIII.

DEVELOPMENT, CONTINUED.

CHAPTER XLIV.

LACTATION.

LIST OF ILLUSTRATIONS.

THE

PHYSIOLOGICAL ANATOMY

AND

PHYSIOLOGY OF MAN.

INTRODUCTION.

The aim of all natural knowledge is to ascertain the laws, which control and regulate the phenomena of the universe. So numerous, and so diversified are these phenomena, that a division of labour has been found, not merely convenient, but absolutely necessary, for the study of them. The position and movements of the planetary system, the crust of the earth, and its various component strata, the treasures hidden in its womb, the abundant vegetation that grows upon its surface, or beneath its waters, and the numberless hosts of animals that dwell upon the land, or in the rivers, lakes and seas, form separate branches of scientific investigation, between which a sufficiently distinct line of demarkation is established by the nature of the objects of inquiry peculiar to each. But, in all departments of science, the same general rules, for conducting the investigation, prevail, and it is only by a close adherence to these, that we can arrive at safe and satisfactory conclusions.

In any scientific inquiry, the first step must be, to form a general notion of the characters and properties of the objects of investigation. In the next place, it is necessary to observe carefully the phenomena which they naturally present; and, if they be within our reach, to produce such variation in them by artificial means (by experiments), as may serve to throw light upon them. If the phenomena, under observation, be complex, we must analyze them, with a view to ascertain the simpler ones, of which they are composed. By this analysis, and by the elimination of such as are merely collateral, we arrive at a phenomenon, uncomplicated, incapable of further subdivision, and fundamental; and this we are contented to receive as an *ultimate fact*, the result of a law in constant and universal operation. The accumulation of observations and experiments affords us Experience; points out the ordinary succession of phenomena, and teaches us the ways of Nature. If these phenomena are found to present a certain uniformity, we are authorized to refer them to the

operation of one common Cause, and we are thus led to the expression of the Law which regulates their occurrence. Proceeding in this way, we are enabled to explain the whole train of phenomena which have been investigated,—that is, to devise a *Theory* which develops the rationale of their occurrence.

But sometimes our experiments and observations throw an imperfect light upon the phenomena which are the subjects of investigation; or the latter are so remote, or so little under our control, as to render both observation and experiment extremely difficult, and, in some cases, impossible. The "instances" which we are enabled to collect, are consequently dubious and obscure, and point darkly, or not at all, to ultimate facts; they present little or no general resemblance, and cannot be properly associated together. Here is no foundation on which to build a theory: but great advantage may be gained, if, with the little light we derive from these particular observations, aided by previous knowledge of general laws, we can frame an *hypothesis*, offering some explanation of the phenomena. The adoption of such an hypothesis, even for a temporary purpose, will "afford us motives for searching into analogies," may suggest new modes of observation and experiment, and "may serve as a scaffold for the erection of general laws."

Previously to the time of Lavoisier, chemists were perfectly familiar with the occurrence of combustion under various circumstances; but the opinions (hypotheses) which prevailed as to the real nature of this process, afforded a very unsatisfactory explanation of it. Subsequently, however, by the labours of Lavoisier, Davy, and others, this complex phenomenon has been observed in all its phases; it has been carefully analyzed, and has been proved to occur in all cases, where substances possessed of strong chemical attractions, or different electrical relations, are brought within mutual influence. The *ultimate fact*, thus arrived at, is, that intense chemical combination always gives rise to the evolution of heat, and, in many instances, to that of light also.

Again, a great number of observations have shown that bodies combine together only in certain quantities, or in multiples of them; that each body has its proper combining quantity, and that it never enters into combination except in that quantity, or some multiple of it. This is an *ultimate fact*, ascertained by numerous experiments, and indicates the law, which is so important in chemistry, that bodies unite with each other in their combining proportions only, or in multiples of them, and in no intermediate proportions. And this, again, has led to the beautiful generalization of Dalton, that the ultimate atoms of bodies are their respective combining quantities, and bear to each other the same proportion as their combining equivalents do.

Or, to take an example from the science which is to form the subject of the following pages. The function of respiration in animals is a very complex process, respecting the nature of which many unsatisfactory hypotheses had been formed, owing to the obscurity in which many of the phenomena, immediately or remotely connected

with it, were involved. Until the law of the diffusion of gases, and of the permeability of membranes by them, had been developed, and until it had been shown that carbonic acid is held in solution in venous blood, no theory of respiration could be framed adequate to explain all the phenomena. It is now proved that, in this process, a true interchange of gases takes place through the coats of the pulmonary blood-vessels, the oxygen of the air abstracting and occupying the place of the carbonic acid of the blood. An admirable example is thus afforded of a most important vital process taking place in obedience to a purely physical law.

Living objects are those which properly belong to the science of Physiology. These are strongly contrasted with the inanimate bodies (which have never lived), to which other branches of natural science refer. At the same time, there are many points of resemblance between them; and as both owe their origin to the same Creative mandate, and are reducible (as will be seen by-and-by) to the same elementary constituents, so they are subject in a great degree to the same physical laws, and are to be investigated according to the same principles of philosophical inquiry.

We propose, in the first place, to compare living, or organized bodies, with inanimate, mineral, or unorganized bodies, and to explain what is meant by the term Life. Secondly, to review briefly, and with reference to their leading distinctions, the phenomena of the vegetable and animal kingdoms. Thirdly, to point out the value of a knowledge of Physiology, especially that of Man, in relation to medicine, and to explain the best mode of pursuing it.

I. Every living Being is *organized*,—that is, composed of different parts or *organs*, each of which has its definite structure, by which it differs from other parts, and is capable of fulfilling a certain end. The complex matter, which enters into the composition of an organized being, or *organism*, is termed *organic* matter, and is obtained by its proximate analysis. The ultimate analysis of this matter resolves it into elementary principles, such as constitute other objects of the universe.

The various bodies that compose the mineral kingdom, do not exhibit the same distinctness, and variety of structure in their component parts, nor is there any adaptation of their parts to separate functions; they are therefore called *unorganized* or *inorganic*, and chemical analysis resolves them into those simple elements which admit of no further subdivision.

Organized bodies are found in two states or conditions. The one, that of *life*, is a state of action, or of capacity for action. The other, that of *death*, is one in which all vital action has ceased, and to which the disintegration of the organized body succeeds as a natural consequence.

An organized body in a state of *active* life exhibits certain processes, by which its growth and nutrition are provided for, and which enable it to resist the destructive influence of surrounding agents—processes, the object of which is to promote the development, and to

preserve the integrity of the body itself. The simplest animal, or vegetable, is an illustration of this remark.

But there are organized bodies in which life may be said to be *dormant*. In these, no actions or processes can be observed, nor any change taking place: yet, if placed under certain favourable conditions, vital activity will soon become manifest. Of this, we have familiar examples in a seed, and in an egg. It is well known, that seeds will retain their form, size, and other properties for a very considerable period; and afterwards, if suitably circumstanced, will exhibit the process of germination as completely as if they had been only recently separated from the parent plant. Eggs, also, may be preserved for a long time without injury to the power of development, or to the nutrition, of the embryo contained within them.

It is worthy of observation, that those processes, which denote vital activity, may be sometimes temporarily suspended, even in fully formed animals and vegetables; and, in such instances, life may be said to *become dormant*. The privation of moisture is the ordinary cause of this interruption to the phenomena of life. In dry weather, mosses often become completely desiccated and appear quite dead, but will speedily revive on the application of moisture. And the common wheel animalcule, although apparently killed by the drying up of the fluid in which it had been immersed, will speedily resume its active movements on being supplied anew with water.

Inorganic bodies may be resolved by ultimate analysis into Oxygen, Hydrogen, Nitrogen, Carbon, and about fifty other substances, which Chemists regard as simple, because they appear to consist of one kind of matter only; that is to say, they have hitherto resisted further decomposition. These elements unite in certain definite proportions to form the compound inorganic substances. And this union may consist either of two simple elements—as oxygen and hydrogen, to form water; oxygen and the metal sodium, to form soda; chlorine and sodium, to form common salt; or, of one binary compound with another similar one, as of sulphuric acid (sulphur + oxygen) with soda (sodium + oxygen), to form sulphate of soda; or, again, of two such salts as the last with one another, as alum, which consists of sulphate of alumina united with sulphate of potassa.

As regards the mode of combination in the first of the examples enumerated in the preceding paragraph, where single equivalents of the elementary bodies unite, there can be but one opinion. In the formation of water, one equivalent of hydrogen combines directly with one equivalent of oxygen. But when one equivalent of one element is united with two or more of the other, to form the compound substance, the mode of combination is not so evident. Peroxide of hydrogen, for example, may either result from the direct combination of one equivalent of hydrogen with two of oxygen, or it may be a compound of one equivalent of water with one of oxygen.

In the second example, in which two binary compounds unite to form a salt, two modes of constitution have been suggested. The first supposes a direct union of a basic oxide with an acid oxide, as of soda (sodium + oxygen) with sulphuric acid (sulphur + oxygen)

again, the organized structure muscle, is formed. And so in other cases.

In the organized body the constituent particles are, as it were, artfully arranged, so as to form peculiar textures, destined to serve special purposes in the living mechanism of the animal or plant to which they belong. The organic compounds which may be obtained from these are devoid of this mechanical arrangement of particles, and it is a beautiful feature of the organized body, that every part has its special office, that there is nothing superfluous, nothing wanting. As each organized body has a certain end to serve in the economy of the living world, so each organ has its proper use in the animal or plant. In this adaptation of parts to the performance of certain functions, we see the strongest evidence of Design; and, amidst much apparent difference of form and obvious diversity of purpose, the anatomist recognizes a remarkable unity of plan—affording incontestable proof that the whole was devised by One Mind, infinite in wisdom, unlimited in resource.

The true proximate principles are those substances which are the first obtained by the analysis of the organized textures; such are *gluten*, *starch*, *lignine*, from the vegetable textures, or *albumen*, *fibrin*, *casein*, from the animal ones. From these again a great variety of compounds has been obtained by various processes, owing to the tendency which their elements have to form new combinations. By boiling starch in dilute acids, it becomes converted into a kind of gum, and starch-sugar. By placing yeast in contact with sugar, the latter is converted into alcohol and carbonic acid, without the yeast affording it any of its chemical constituents; and, in the germination of barley, or of the potatoe, a peculiar substance is formed, the contact of which with the starch of the barley or potatoe converts it into sugar. Innumerable examples might be quoted from various vegetable compounds, showing that the affinity, which holds together the elements of organic substances, is so feeble, that it affords but slight resistance to their entrance into new combinations. In this way a large class of organic matters is formed, which it seems proper to distinguish from the true proximate principles, under the name of *secondary organic compounds.*

In analyzing the true proximate principles of organic substances, it is found that they consist for the most part of three or four of the essential simple elements, and that, as many of them contain a large number of atoms, their combining proportion is represented by a very high number. Respecting the mode of combination of these elements much uncertainty prevails. Some chemists consider them united equally with each other, and regard the organic principles themselves as ternary or quaternary compounds of them. But others have suggested a mode of combination more analogous to that of inorganic substances (see pages 28, 29); namely, that two or three of the elements form a compound radicle, with which the remaining one unites to form a binary compound. In a body, for example, consisting of three elements, two would form the compound radicle, or, in one composed of four elements, three would constitute it. This mode

of composition has been rendered more probable in the secondary organic products, than in the true proximate principles: and it may be illustrated by an example taken from the former class. Ether is composed of four atoms of carbon, five atoms of hydrogen, and one atom of oxygen: the carbon and hydrogen constitute a hypothetical compound radicle, called ethyl, which is united with one atom of oxygen: so that ether is an oxide of ethyl, and its formula may be expressed $C_4 H_5 + O$.

Among the secondary organic products of the vegetable class we meet a few instances of binary compounds of simple elements; but the great majority of proximate organic elements, whether primary or secondary, are composed of three or four essential elements.

In contrasting, then, the chemical composition of organic with that of inorganic substances, we perceive that, applying the binary theory to both classes of substances, their mode of combination is strictly analogous; there being, however, this distinction, that, among organic substances combination with a compound radicle is the prevailing mode, and that the union of two simple substances is rare. If, on the other hand, we adopt the theory of oxy-acid salts for inorganic compounds, and view the organic principles as ternary or quaternary compounds of simple elements, each to each, then it is evident that the most marked difference must exist between the two classes of compounds, the latter being formed on principles entirely dissimilar from those which regulate the composition of the former.

It is probable, however, that the progress of Chemistry will show that the binary theory is applicable to both classes of substances, and that the same mode of chemical composition prevails through both kingdoms of Nature.

If so much uncertainty exists in reference to the manner of combination of the simpler elements to form organic compounds, it is no wonder that the attempts of chemists to produce them by artificial processes should have met with so little success. No one has succeeded in the synthesis of any of the true proximate principles; and, indeed, it is very questionable whether any of those products of a vital chemistry will ever be produced elsewhere than in the living organism. (The formation of urea, a secondary organic compound, has been effected by Wöhler from the cyanate of ammonia, by depriving it of a little ammonia through the action of heat. And it must be admitted, as no unimportant step in the synthesis of organic compounds, that nitrogen gas has been found to unite with charcoal, under the influence of carbonate of potassa at a red heat. The cyanide of potassium, which is thus formed, yields ammonia, when decomposed by water; so that cyanogen, and, through cyanogen, ammonia, can be primarily derived from their respective elements contained in the inorganic world. (*Graham's Chemistry*, p. 709, [Am. Ed. p. 671].) Allantoin, an analogous compound to urea, and formic acid, have likewise been artificially produced.)

We proceed from this review of the chemical constitution of organic and inorganic substances, to compare them together in other respects.

In examining an organic substance which is *organized*, i. e., so constructed as to form part of a living organism, we find it to possess very distinctive characters. It generally contains water in considerable proportion; its form is more or less rounded and free from angularity, and it is never crystallized. When considerable hardness or density is required, the quantity of water is small, and an inorganic material is combined with the organic matter; as, in bones, phosphate of lime with the gelatine of the bone, or, in plants, silex with their epidermic tissues.

An organized body is composed of parts, distinct from each other in structure and function, and it may be subdivided into a series of textures, each differing from the others in physical and vital properties. The existence of a great variety of textures, in an animal, is an indication of a high degree of organization. Among the lowest organized creatures there is much uniformity of structure, although variety of parts or organs. Still these creatures by their actions show that materials of different properties must exist throughout their bodies.

Fig. 1.

Primary organic cell, showing the cell-membrane, the nucleus, and the nucleolus.

The simplest and most elementary organic form, with which we are acquainted, is that of a cell, containing another within it (*nucleus*), which again contains a granular body (*nucleolus*). (Fig. 1.)

This appears, from the interesting researches of Schleiden and Schwann, to be the primary form which organic matter takes when it passes from the condition of a proximate principle to that of an organized structure.

The bodies of some animals and of some plants, are composed almost entirely of cells of this kind; and in the early development of the embryo, all the tissues, however dissimilar from each other, consist at first of nucleated cells, which are afterwards metamorphosed into the proper elements of the adult texture.

An organized body possesses a definite form and disposition, not only as regards its component parts, but likewise when viewed as a whole. Each organized body has its appropriate and specific shape; and to each a certain size is assigned. To observe and classify the wonderful diversity of form exhibited by plants and animals, has given employment to Naturalists in all ages; and the sciences of Zoology and systematic Botany have been founded upon the results of their labours.

Every organized body is limited in its duration; it has "its time to be born and its time to die," and at death it passes by decomposition into simpler and more stable combinations of the inorganic elements.

In their origin, organized bodies are generally, if not always, derived from similar ones. Some have supposed that out of decaying vegetable or animal matter minute animals or plants of other kinds may be formed: but it seems most probable that in those cases in

which they had been supposed to be formed, the seeds or eggs, or even the parents themselves, had been concealed in the decaying matter, or floated in the surrounding atmosphere. Recent experiments throw considerable doubt upon this doctrine of the *spontaneous generation* of organized bodies, by showing that neither vegetation nor the development of animalculæ will go on in fluids which have been subjected to such processes as must inevitably kill whatever germs may have been diffused around or throughout them. In the present state of our knowledge it may be said, that the Harveian maxim, "Omne vivum ex ovo," is the rule; and that if there be any other mode in which the development of living beings takes place, it is the exception. The progress of Anatomical knowledge is every day revealing to us the organs, and the mode of generation in the minutest and the least conspicuous forms of vegetable and animal life; and thus the doctrine, which supposes that living objects may arise by a sort of conjunction of the elements of decomposing organic matter, becomes more and more improbable.

How beautiful is the provision which this power, possessed by organized bodies, of generating others, affords, for preserving a perpetual succession of living beings over the globe! The command, "Increase and multiply," has never ceased to be fulfilled from the moment it was uttered. Every hour, nay, every minute, brings into being countless myriads of plants and animals, to supply in lavish profusion the havoc which death is continually making; and it is impossible to suppose that the earth can cease to be in this way replenished, until the same Almighty Power, that gave the command, shall see fit to oppose some obstacle to its fulfillment.

In addition to this power of propagation, organized bodies enjoy one of conservation and reproduction. Solutions of continuity, the loss of particular textures, whether resulting from injury or from disease, can be repaired. Parts, that have been removed, may be restored by a process of growth in the plant or animal, and (in some animals the reproductive power is so energetic, that if an individual be divided, each segment will become a perfect being.) This power of reproduction is greater, the more simple the structure of the organized body; the more similar to each other are the constituent parts, the more easy will reproduction be. Numerous examples of this power may be adduced,—the healing of wounds, the adhesion of divided parts are familiar to every one. New individuals are developed from the cutting of plants: the division of the hydra into two, gives rise to the production of two new individuals. If a Planaria be cut into eight or ten parts, according to Dugès, each part will assume an independent existence.

The power of reproducing single parts only, is possessed by animals higher in the scale. In snails, part of the head, with the antennæ, may be reproduced, provided the section have been made so as not to injure the cerebral ganglion. Crabs and lobsters can regenerate their claws, when the separation has taken place at an articulation; and spiders enjoy the same power. In lizards, the tail, or a limb,

can be restored, and in salamanders the same phenomenon has been frequently witnessed.

Organized bodies can appropriate and assimilate to their own textures other substances, whether inorganic or organic. This process is that which is most characteristic of living creatures: in virtue of it animals and plants are continually adding to their textures new matter, by which they are nourished. Plants appropriate their nutriment from the inorganic kingdom, as well as from decaying organic matter; animals, chiefly from organic matters, whether animal or vegetable. Both possess the wonderful power of re-arranging the constituents of these substances into forms identical with those of the elements of their various tissues—and of thus making them part and parcel of themselves.

Together with a process of supply, there is one of waste continually in operation. Animals and plants are ever throwing off effete particles from their organisms. These, under the name of *excretions*, appear in various forms—either as inorganic compounds, or as secondary organic products. Thus, carbonic acid is given off in large quantities from animals; water, likewise, forms a considerable portion of their excreted matter, and serves to hold in solution salts, and secondary organic compounds, which result from the waste of the tissues. In this way, also, urea, lithic acid, and biliary matters are excreted. In plants, water is excreted from the leaves, a phenomenon which has been compared to the perspiration of animals; and various other excretions, which are sometimes made to serve an additional purpose in the economy of the vegetable, besides that of getting rid of superfluous matter, are doubtless formed by the secondary combinations of the effete particles of their textures.

These two processes, *excretion*, or the expulsion of effete particles, and *assimilation* of substances from without, are necessarily mutually dependent. As long as new matter is being appropriated, old particles must be thrown off, otherwise growth would be unlimited—and were excretion alone to go on, the destruction of the organism must speedily ensue, by the gradual waste of the tissues, to which no new supply was afforded. In both processes new combinations are taking place, as it were, in opposite directions; in the one from the simple to the complex to form organized parts, in the other, from the complex constituents of the textures to the simple organic, or inorganic compounds.

As each texture of the organism has this tendency to change during life, so, the whole organism tends to decomposition, when death puts a stop to all further absorption of nutritive matters. Dead organized matter is speedily dissipated under certain conditions. These are the presence of air, moisture, and a certain temperature, or contact with an organic substance which is itself undergoing decomposition. The affinity which held together the elements of the organic substances is destroyed by the cause which occasioned their death, and they are set free to obey new affinities and form new compounds.

When we consider the large number of equivalents which enter into the formation of each molecule of organic compounds, it need

[illegible]

[illegible] which distinguishes the mechanism of an animal or plant from the machines of human construction. Yet the living organism is not the less dependent for the continuance, nay, for the very existence of those actions upon the ordinary agencies of nature. Light, heat, the atmosphere, chemical affinity, each has its share in promoting the functions in the play of which Life consists: all are more or less necessary to the integrity of these actions: and it is contrary to experience to suppose that Life can be manifested without their co-operation. Yet we cannot say that Life is produced by, or is the result of, these agencies. It is equally contrary to experience to find the manifestation of Life in other than organized bodies. Nevertheless, it cannot be affirmed that organization is the cause of Life, for without the other agents no vital action occurs, and it has already been shown that the organization of

new matter is effected only by living bodies. The mutual co-operation of organized matter with the forces at work in the inorganic world, is necessary to the development of vital phenomena.

The term Life, then, may be regarded as denoting an ultimate fact in science, which may be thus expressed; that certain compounds of matter—which, as being artfully arranged in a particular form for a special end, and associated together by a certain mechanism, are called *organized*—do, by their co-operation with physical and chemical forces, manifest a train of phenomena, which are of the same, or of an analogous kind, for all organized beings; that is to say, they manifest the phenomena of Life. All organized substances, capable of thus co-operating with the other natural agencies, are called *living;* and, although they may not be positively in action, they are yet alive, as being ready to act when the complementary conditions to vital action shall be supplied to them. Thus the seed is alive, although not in action; but, immediately it is brought into contact with moisture and heat, life is manifested. Hence these agents, moisture, heat, light, &c., are said to act as *vital stimuli.* The organic matter, in becoming part of a living machine, acquires certain properties, very different from what it possessed before; these are called *vital properties:* they continue as long as the organization remains unchanged. For example, a certain proximate element is organized to form muscle; it then acquires the property of contractility, which it retains during life.

According to our experience, organic matter derives vital properties in by far the majority of instances, and probably in all, from a previously existing organism. The egg, while within the body of the mother, acquires vital properties; and it manifests an independent life when it is laid, if the requisite conditions (vital stimuli) are then supplied. Thus is life transmitted from one living being to another; and the life of a present generation of animals and plants has its source in that of a previous generation. If we trace a race upwards, through generations innumerable, to that which first flourished on the earth, we find the true source of vital action to be in Him, "in whom we live, and move, and have our being."

Thus, then, out of the same elements of which the inorganic kingdom consists, God has created a series of material substances, which by their action and reaction with other physical agencies, exhibit, apparently in a spontaneous manner, the phenomena of Life, and manifest a series of peculiar forces capable of opposing and controlling the other forces of nature. While these substances retain a perfect organization, and are supplied with their proper stimuli, vital actions go on without interruption, and no changes take place in the matter of the organism, excepting such as result from its proper affinities. But no sooner is the integrity of its structure destroyed, or the influence of the vital stimuli withdrawn, than action ceases, the organism *dies*, and the organic matter yields up its elements to form new compounds, a large proportion of which are inorganic.

Many are not content with this simple expression of facts, and seek a theory to explain the phenomena of organized bodies, and to account

for the mysterious actions of Life. The ingenuity of philosophers has been not a little taxed for this purpose; and the history of the rise and fall of many an hypothesis, which has been framed upon this subject, affords a salutary warning to those who may be tempted to wander into the regions of speculation and fancy, deserting the safe and beaten path of inductive reasoning.

It does not fall within the scope of this work to examine the various theories of Life. One or two, however, we deem it right to notice, with the hope of at once exposing their inadequacy, and elucidating more fully the statement above given respecting Life.

From a very early period in the history of natural science, there has been a tendency to ascribe these effects to a certain principle, or Entity, possessing powers and properties which (however men may try to impress themselves with the contrary notion) entitle it to rank as an intelligent agent. It is true, that, according to most of the advocates of this doctrine, this power is supposed to be superintended and controlled by the Deity himself, and, by this supposition, they have screened themselves against the accusation of attributing to a creature the powers of the Creator.

A little examination of this doctrine will show, that is has no pretensions to the title of a theory.

Aristotle attributed the organization of animals and vegetables, and the vital actions exhibited by them, to a series of *animating principles*, (ψυχαι,) differing according to the nature of the organized bodies constructed by them, and acting under the direction of the Supreme animating principle (φυσις). He supposes that each particular kind of organized body had its proper animating principle, or ψυχη, and that the variety of the former really depended upon certain original differences in the nature of the latter, so that every distinct species of animating principle would necessarily have its appropriate species of body.

Harvey, likewise, assumes the existence of an *animating principle*, by which every organism is moulded into shape, out of materials furnished by the parent, and which, pervading the substance, regulates the various functions of its corporeal residence. But, at a subsequent stage of his inquiries, in assigning the blood as the special seat of this principle, he advances another supposition totally at variance with his previous hypothesis; namely, that as, during the development of the chick in ovo, the blood is formed and is moved, before any vessel, or any organ of motion exists, so in it and from it originate, not only motion and pulsation but animal temperature, the vital spirit, and *even the principle of life itself*. So completely biased were the views of this illustrious man, by his exaggerated notions respecting the nature and properties of the blood!

The celebrated John Hunter, who does not appear to have been acquainted with the views expressed by Harvey, revived a somewhat similar hypothesis; and it is curious that the same fact should have so attracted the attention of both as to have given the first impulse to their speculations. This fact was, that a prolific egg will remain sweet in a warm atmosphere, while an unfecundated one will putrefy. The

views of Hunter have been received with very general favour by English physiologists.

Hunter ascribes the phenomena of life to a *materia vitæ*, diffused throughout the solids and the fluids of the body. This *materia vitæ* he considers to be "similar to the materials of the brain:" he distinguishes it from the brain by the title "*materia vitæ diffusa*," while he calls that organ "*materia vitæ coacervata*," and supposes that it communicates with the former through the nerves, the *chordæ internunciæ*. And Mr. Abernethy, in commenting upon these views, explains Mr. Hunter's *materia vitæ* to be a subtile substance, of a quickly and powerfully mobile nature, which is superadded to organization and pervades organized bodies; and this he regards as, at least, of a nature similar to electricity.

Müller advocates the presence of an "*organic force*," resident in the whole organism, on which the existence of each part depends, and which has the property of generating from organic matters the individual organs necessary to the whole. "This rational creative force is exerted in every animal strictly in accordance with what the nature of each requires; it exists already in the germ, and *creates* in it the essential parts of the future animal."

An hypothesis, not dissimilar to that last mentioned, is maintained by Dr. Prout, and, as appears to us, it has been pushed by him to the utmost limits which the most fanciful speculation would admit of. He supposes that a certain *organic agent* (or agents) exists, the intimate nature of which is unknown, but to which very extraordinary powers are ascribed. It is superior to those agents whose operations we witness in the inorganic world: it possesses the power of controlling and directing the operations of those inferior agents. "If," says Dr. Prout, "the existence of one such organic agent be admitted, the admission of the existence of others can scarcely be withheld; *for the existence of one only is quite inadequate to explain the infinite diversity among plants and animals.*" "In all cases it must be considered an ultimate principle, endowed by the Creator with a faculty little short of intelligence, by means of which it is enabled to construct such a mechanism from natural elements, and by the aid of natural agencies, as to render it capable of taking further advantage of their properties, and of making them subservient to its use."

The hypotheses of Aristotle, Müller, and Prout, and the earlier of those proposed by Harvey, seem all alike; they assume that organization and life are directed and controlled by an Entity, or Power, "endowed with a faculty little short of intelligence," the ψυχη of Aristotle, the animating principle of Harvey, the organic force of Müller, and the organic agent of Prout. What the mechanism may be by which this entity acts, they do not determine; but it is evidently such as bears no analogy to any known natural agency. Its existence is independent of the organism, for it has directed both the organizing process and the living actions of the being. Whence then is it derived? According to Müller, from the parent, for it exists in the germ,—it derives its powers from the same source, and its pedigree may, therefore, be traced to the first created individual of each

species of animal or plant. Are we to conclude, then, that organic agents generate organic agents, and transmit their powers to their offspring? Or must we assume, that, for each newly generated animal or plant, a special organic agent is deputed "to control and direct" its organization, development, and growth?

The modern advocates of this doctrine have been driven to its adoption, from the difficulty (or, as they conceive, the impossibility) of explaining the phenomena of organization and life on principles analogous to those on which the changes of inorganic matter may be accounted for: this difficulty consisting in the supposed existence of certain differences in the mode of combination of the elementary constituents of organic and inorganic compounds, seconded by the fact, of the synthesis of organic compounds having hitherto baffled the chemist's art. It has puzzled them to think that out of the same elementary and proximate principles, so infinite a variety of animals and plants could be formed; and Dr. Prout has been especially staggered by the fact, that carbon and water, which contribute so largely to the formation of various organisms, have never, although aided by heat, light, and electricity, when out of an organized body, *and left entirely to themselves*, been able to unite, either in virtue of their own properties or from accident, so as to form any plant or animal, however insignificant.

In the first place, let it be observed, that many of the phenomena of life may be accounted for on physical or chemical principles. The changes effected in the air and in the blood by respiration, the phenomena of absorption, and, in some degree, those of secretion, are the results of purely physical processes. It is in the highest degree probable that many of the actions of the nervous system are due to physical changes in the two kinds of nervous matter, substances of complex constitution and high equivalent number, and therefore prone to change. Stomach-digestion is now known to be a chemical solution; the generation of heat is due to the same chemical phenomenon as will give rise to it in the inorganic world; and electricity is also similarly developed within the body. How entirely dependent on physical changes are the senses of vision and hearing, and how completely are their organs adapted to the laws of light and sound! And, doubtless, a further insight into the nature of the various organic processes will reveal to us a closer analogy between the laws by which the two great kingdoms of nature are governed.

Nor is there so great a chasm between matters organic and inorganic, as to chemical composition, as some would have us believe. It has already been shown that modern chemical research tends to prove a similarity as regards the mode of combination of the elements in both; and the labours of chemists have been crowned with success in forming some organic products by artificial means.—(See p. 31.)

And let it not be forgotten that the living laboratory of the animal and plant is one well stored with means for analysis and synthesis: the continual introduction of new material gives full scope to the play of chemical affinity, and at every point the constant attendants of

chemical action, heat and electricity, are developed. May it not reasonably be inferred that these agencies, which the chemist can so readily turn to account in his artificial processes, are not idle in the work of combination and decomposition in the living body? A great difference as to sensible qualities, in the various organic products, by no means implies great difference of chemical constitution, for it is well known that the addition or removal of a single atom of one of the ingredients of any compound is sufficient to produce a substance with totally new properties; and such is the complex nature of organic molecules, that the attraction between their component elements yields readily to disturbing causes.

But how shall we explain the strange process of organization, in the production of that infinite diversity of forms, that "insatiable variety of Nature," which is so conspicuous in the vegetable and animal kingdoms? Must we imagine the creation, in corresponding number and variety, of a duplicate order of beings, whose duty it shall be to preside over the development of each species, and to impress each with its peculiar characters? Or does it not seem more consistent with that grand simplicity, which the phenomena of nature everywhere present, to suppose that the organization of animals and plants, in such great variety, is the result of the primary endowment of organic matter, at the creation of the first parents of each species, by the Almighty? The animal or vegetable matter of each species was created to propagate after a certain fashion, and after that only; the organic cells, of which these organisms consist in the early stages of development, have the power of evolving the adult tissues of animals and plants of their own species only: the simple volvox develops, from its interior, organic cells which become volvoces; and the cell, which forms the ovum of the elephant or the mouse, is able, by an inherent power of multiplication, to evolve the skeletons and organs of each of those animals respectively.

The peculiar endowments of the organic matter, composing the various tribes of animals and plants, are transmitted from parent to offspring. But they admit of certain modifications under the influence of circumstances affecting the parents, as is proved both in the animal and vegetable kingdoms in the production of hybrids. "Two distinct species of the same genus of plants," says Dr. Lindley, "will often together produce an offspring intermediate in character between themselves, and capable of performing all its vital functions as perfectly as either parent, with the exception of its being unequal to perpetuating itself permanently by seed; should it not be absolutely sterile, it will become so after a few generations. It may, however, be rendered fertile by the application of the pollen of either of its parents; in which case its offspring assumes the character of the parent by which the pollen was supplied." The same thing precisely occurs among animals, and the mixed offspring, or mule, produced by the union of different species is incapable of breeding with another mule; but not so with an animal of the same species as either of its parents. How entirely inadequate is the theory of organic agents to explain these occurrences; it cannot, surely, be

maintained that a mixed organic agent is produced from the conjunction of the organic agents of the dissimilar species to direct the formation of this mixed organism!

The remarkable fact, that the various tribes of the human race, dissimilar as they are, were derived from the first created pair, may be adduced as a striking illustration of the influence of physical agency in modifying organic development. The most potent cause of these changes has been climate; but particular customs and usages, connected with the uncivilized state, have not been without their influence. Climate also produces considerable modifications in the size and other characters of the lower animals. Sturm affirms that cattle transported from the temperate zones of Europe (Holland or England) to the East Indies, become considerably smaller in their succeeding generations.

The theory of organic agents affords no more satisfactory explanation of disease, or of death. In both cases the organic agent must be at fault; for as it is the sole guide and controller of the organizing process, so it is not to be supposed that anything can go astray, except under its guidance. And yet it seems impossible to imagine that the ordinary causes of disease could affect such an entity. On the other hand, any physical or mental cause, general or local, affecting the substance of which the body is composed, may so alter and modify the affinities of its particles as to occasion a material disturbance in their actions; and it is not difficult to conceive that this disturbance may be of such a kind as to put a stop to vital action immediately or remotely.

So much for the dependence of Life and Organization on a controlling and directing Entity. The sagacity of John Hunter led him to reject this doctrine entirely; but, as he completely passed over the influence of the natural agencies of inorganic nature upon organized beings, he was forced to assume the presence of a peculiar material substance, pervading and giving vital properties to solids and fluids: yet such a constituent of the body ought to be demonstrable by chemical or other means. It is clear that this *materia vitæ* cannot be, as Mr. Abernethy suggested, electricity, or anything akin to it. Electricity requires for its development the reciprocal action of different kinds of matter, and it is abundantly evolved in various animal processes, as a necessary result of chemical laws. If, therefore, organization and vital actions depended upon electricity, this agent would, at once, be formed by, and direct the formation of each organism.

Mere composition of matter does not give life, says Hunter; if he had added, that organized bodies acted on by, and co-operating with, certain vital stimuli, developed vital actions, there would have been no need for the assumption of a *materia vitæ*. The resistance which living animals introduced into the stomach are capable of affording to its solvent powers, and the digestion of the walls of the stomach by its own fluid after sudden and violent death, seemed to denote that the dead animal, or dead stomach, had lost a something which previously protected them against the influence of the gastric fluid.

But this is no more than a case familiar to chemists, viz., the influence of a stronger affinity controlling a weaker. When iodide of potassium is mixed with a solution of starch, no change ensues; but, if a minute quantity of chlorine be added, a blue iodide of starch is instantly formed; the superior affinity of the iodine for the potassium hindered the union of the former with the starch; but, as soon as the iodine was set free by the stronger attraction between the potassium and the chlorine, it speedily united with the starch. So, in the living animal, the affinity of its component particles for each other is greater than their affinity for the gastric fluid; but in the dead animal the former affinity is destroyed, the latter comes into play. Whether is it more philosophical to assume the removal of a particular agent, for which removal no cause can be assigned; or, to state the simple fact of the physical difference between dead and living organic matter?

II. It is very difficult to define a precise boundary between the vegetable and animal kingdoms. The lowest animals exhibit so much of the plant-nature, that naturalists are as yet undecided as to the true location of some species. The common sponge, for instance, is claimed for each kingdom.

The various processes by which are effected the ceaseless motion and change, so characteristic of living beings, are called, in physiological language, *Functions.*

The functions, which are common to all organized beings, have a twofold object; the preservation of the individual, and the propagation of the species. Those destined for the former purpose are the *Nutritive Functions:* those for the latter are comprehended under the general title *Generation.*

The first step in the nutritive functions of both plants and animals, is to form a fluid, which contains all the elements necessary to nourish the various textures, and to supply materials for the secretions. This fluid is, in plants, *the sap;* in animals, *the blood.*

In both classes of beings a process of *absorption* precedes the full development of the nutritive fluid: it is by this means that material is obtained for its formation. Within the plant or animal it becomes more completely elaborated.

In plants, the absorption takes place by the spongioles of the roots. A fluid, already prepared in the soil,—water, holding in solution carbonic acid and various mineral substances,—passes through them into the vegetable organism, without undergoing any reduction or preparation during its transit. In animals, however, the food experiences much change, and a more or less elaborate process of *digestion* takes place, before a fluid is formed, capable, when absorbed, of furnishing the materials of the blood.

Plants, fixed by their roots in the soil, imbibe from it their nutriment. Animals, obtaining food from various sources, introduce it into a digestive cavity, where it is prepared for absorption.

The presence of a digestive organ, or stomach, is characteristic of animals. The only instances in which a similar organ may be supposed to exist in the vegetable kingdom are to be found in those

remarkable modifications of leaves, called pitchers (*ascidia*) in *Nepenthes*, *Sarracenia*, and *Dischidia*. In the last two plants, these organs certainly serve to retain and dissolve the bodies of insects in the fluid which partially fills them: in *Sarracenia*, according to Mr. Burnett, the fluid contained in the pitchers is very attractive to insects, which, having reached its surface, are prevented from returning by the direction of the long bristles that line the cavity. The dissolved food is then absorbed into the plant.

On the other hand, the animal kingdom affords some exceptions to the presence of a stomach. In such animals, the absorption of nutrient fluid takes place by a general surface. The *Volvox globator* has no inlet to its interior but through the pores in its walls. A parasite of the human body, the *Acephalocyst*, also derives its nutriment by imbibition through its walls. A familiar example is the *Acephalocystis endogena*, or pill-box hydatid of Hunter. It consists of a globular bag, closed at all points, containing a limpid fluid, capable of growth, and of reproduction by the development of gemmules from the inner surface of the sac. The *Echinococcus* is also nourished by direct absorption into the walls of the globular sac of which it consists.

Some difference may be noticed as regards the nature of the food in animals and plants. The former derive their nutriment entirely from the organized world, unless, indeed, we suppose that the nitrogen absorbed in respiration contributes to their sustenance. Plants appropriate inorganic elementary matters for food, as carbon, carbonic acid, ammonia, &c. "Inorganic matter," says Liebig, "affords food to plants; and they, on the other hand, yield the means of subsistence to animals. The conditions necessary for animal and vegetable nutrition are essentially different. An animal requires for its development, and for the sustenance of its vital functions, a certain class of substances which can only be generated by organic beings possessed of life. Although many animals are entirely carnivorous, yet their primary nutriment must be derived from plants; for the animals upon which they subsist receive their nourishment from vegetable matter. But plants find new nutritive material only in inorganic substances. Hence one great end of vegetable life is to generate matter adapted for the nutrition of animals out of inorganic substances which are not fitted for this purpose."

The nutrient fluid, however formed, is distributed throughout the textures of the plant, or animal, by vital or physical forces, or by the junction of both; and the function, by which this is effected, is called *Circulation*. In plants, this function is very simple, and is performed without the agency of a propelling organ; but, in the greatest number of animals, such an organ, a *heart*, is the main instrument in the distribution of the blood. In animals, then, there is a true circulation; the fluid setting out from, and returning to, the same place. But, in plants, the fluid is found to circulate, or rotate, within the interior of cells, as in *Chara* and *Vallisneria*, the fluid of one cell not communicating with that of the adjacent ones, or to pass up from the

spongioles in an ascending current, and to descend in another set of vessels.

But in many simple animals, some entozoa, for example, and polygastrica, there is no good evidence of the existence of any circulation at all; their textures imbibing the fluid in which they live.

The presence of atmospheric air is necessary to the existence of all organized beings. The air both passes by endosmose into their nutrient fluids, and receives from them certain deleterious gases developed in their interior. The function, by which the fluids are thus aërated, is called *Respiration*. In plants, the introduction of atmospheric air conveys nutriment to the organism; carbonic acid and ammonia are thus introduced; the former is decomposed, its carbon is assimilated, and its oxygen is exchanged for a fresh supply of atmospheric air. As the agent in the decomposition of the carbonic acid is light, it is evident that the generation and the evolution of oxygen can take place only in the day-time. Consequently, during the night, the carbonic acid, with which the fluids of the plant abound, ceases to be decomposed, and is exhaled by its leaves. Hence, plants exhale oxygen in the day-time, and carbonic acid at night.

In animals, carbonic acid accumulates in the blood during its circulation; and, when the atmosphere is brought to bear upon the capillary vessels containing the blood charged with this gas, a mixture takes place through the delicate walls of the vessels, the atmospheric air passing in, and carbonic acid, with nitrogen and oxygen, in certain proportions, escaping. Thus the evolution of carbonic acid, and the absorption of oxygen and nitrogen, are the characteristic features of respiration in animals.

It is highly interesting to notice, how plants are thus subservient to the well-being of animals, in the respiratory function, as well as in preparing nutriment for them. By their respiration they serve to purify the air for animals; for, in absorbing the carbonic acid from the atmosphere, they are continually depriving it of an element which, if suffered to accumulate beyond certain bounds, would prove destructive to animal life.

From the fluids of animals and plants, certain materials are separated by a singular process, nearly allied in its mechanism to nutrition, and called the function of *Secretion*. The secreted matters are various, and have very different ends: in some cases being destined for some ulterior purpose in the economy; in others, forming an excrement, the continuance of which in the organism would be prejudicial to it.

The function, which has for its object the propagation of the species, *Generation*, presents many points of resemblance in plants and animals. In the former it is cryptogamic, or phanerogamic; in the latter, non-sexual, or sexual. In the phanerogamic and sexual, the junction of two kinds of matter furnished by the parents is necessary to the development of fertile ova. In the cryptogamic and non-sexual generation, the new individual is developed by a separation of particles from the body of the parent, by which the new formation is

nourished until it has been so far matured as to be capable of an independent existence.

The functions, hitherto enumerated, may be called *organic*, as being common to all organized beings; but there are others which, as being peculiar to, and characteristic of, animals, may be appropriately designated *animal* functions.

The prominent characteristic of animals is the enjoyment of *Volition* or *Will*, which implies necessarily the possession of *Consciousness*. Our knowledge of the share which consciousness and the will have in the production of certain phenomena of animal life, is derived from the experience which each person has of his own movements, and a comparison of them with the actions of inferior animals. We are conscious that, by a certain effort of the mind, we can excite our muscles to action; and when we see precisely similar acts performed by the lower creatures, with all the marks of a purpose, it is fair to infer that the same process takes place in them as in ourselves. Moreover, we learn by experience, that injury or disease of the nerves, which are distributed to our muscles, destroys the power of accomplishing a certain act, but does not affect the desire or the wish to perform it: and experiments tell us that the division of the nerves of a limb in a lower animal destroys its power over that member; while its ineffectual struggles to move the limb obviously indicate that the will itself is not affected by the bodily injury, though its powers are limited by it.

Again, certain external agents are capable of affecting the mind, through certain organs, thus giving rise to *Sensations*. Light, sound, odour, the sapid qualities of bodies, their various mechanical properties, hardness, softness, &c., are respectively capable of producing corresponding affections of the mind, which experience leads us to associate with their exciting causes, and which may be agreeable, and produce *pleasure*, or the reverse, and give rise to *pain*.

In a similar way to that by which we learn that the will stimulates our muscles through the nerves, we can ascertain that the nerves are the channels through which our sensations also are excited. "Certain states of our bodily organs are directly followed by certain states or affections of our mind; certain states or affections of our mind are directly followed by certain states of our bodily organs. The nerve of sight, for example, is affected in a certain manner; vision, which is an affection, or state of the mind, is its consequence. I will to move my hand; the hand obeys my will so rapidly, that the motion, though truly subsequent, seems almost to accompany my volition, rather than to follow it." (Dr. Brown. *Philosophy of the Human Mind*, p. 106.)

And in all the inferior animals, possessed of like organs, there can be no doubt that sensations may be produced similar to those which arise in the human mind. In many of them, indeed, the sense of sight, hearing, or smell seems much more acute than in man, and affords examples of a beautiful and providential provision for the peculiar sphere which the creatures are destined to occupy. The unerring precision of the beast or bird of prey in pouncing upon its victim—

the accuracy with which the hound tracks by its scent the object of its pursuit—or, the quickness with which most of our domestic animals detect sounds and judge of their direction, are familiar illustrations of the superiority of these senses in animals whose general organization is inferior to that of man.

There are few animals, however small and insignificant, in which we cannot recognize evidence of a controlling and directing will. But even in those few, in which voluntary movements are not distinctly to be discerned, the presence of a special system of organs, with which in the higher animals volition and sensation are associated, namely, *a nervous system*, serves as a characteristic distinction from plants.

A power of perception, and a power of volition, together constitute our simplest idea of *Mind;* the one excited through certain corporeal organs, the other acting on the body. Throughout the greatest part of the animal creation mental power exists, ranging from this its lowest degree—a state of the blindest instinct, prompting the animal to search for food—to the docility, sagacity, and memory of the brute; and to its highest state, the reasoning powers of man.

The phenomena of Mind, even in their simplest degree of development, are so distinct from anything which observation teaches us to be produced by material agency, that we are bound to refer them to a cause different from that to which we refer the phenomena of living bodies. Although associated with the body by some unknown connecting link, the mind works quite independently of it; and, on the other hand, a large proportion of the bodily acts are independent of the mind. The immortal Soul of man, *divinæ particula auræ*, is the seat of those thoughts and reasonings, hopes and fears, joys and sorrows, which, whether as springs of action, or motions excited by passing events, must ever accompany him through the checkered scene in which he is destined to play his part during his earthly career.

Although the animals, inferior to man, exhibit many mental acts in common with him, they are devoid of all power of abstract reasoning. "Why is it," says Dr. Alison, "that the monkeys, who have been observed to assemble about the fires which savages have made in the forests, and been gratified by the warmth, have never been seen to gather sticks and rekindle them when expiring? Not, certainly, because they are incapable of understanding that the fire which warmed them formerly will do so again, but because they are incapable of abstracting and reflecting on that *quality* of wood, and that *relation* of wood to fires already existing, which must be comprehended, in order that the action of renewing the fire may be suggested by what is properly called an effort of reason."

Yet animals are guided by *Instinct* to the performance of certain acts which have reference to a determinate end: they construct various mechanical contrivances, and adopt measures of prudent foresight to provide for a season of want and difficulty. None of these acts could be effected by man without antecedent reasoning, experience, or instruction. But animals do them without previous

assistance; and the young and inexperienced are as expert as those which have frequently repeated them. "An animal separated immediately after its birth from all communication with its kind, will yet perform every act peculiar to its species, in the same manner, and with the same precision, as if it had regularly copied their example, and been instructed by their society. The animal is guided and governed by this principle alone; by this all its powers are limited, and to this all its actions are to be ultimately referred. An animal can discover nothing new; it can lose nothing old. The beaver constructs its habitation, the sparrow its nest, the bee its comb, neither better nor worse than they did five thousand years ago."

In plants there is no nervous system; there are no mental phenomena. The motions of plants correspond in some degree with those movements of animals in which neither consciousness nor nervous influence participates. Such movements are strictly organic, and result from physical changes produced directly in the part moved. Amongst the most interesting examples of these movements are those of the *Mimosa pudica*, the *Dionæa muscipula*, and the *Berberis*.

III. It is the province of Physiology to investigate the ways in which the functions of living beings are effected; and this investigation naturally involves the examination of their mechanism, of the chemical constitution, and of the properties of their component textures. The study of Anatomy must always accompany that of Physiology, on the principle that we must understand the construction of a machine before we can comprehend the way in which it works. The history of physiology shows that it made no advance until the progress of anatomical knowledge had unfolded the structure of the body. There is so much of obvious mechanical design in the intimate structure of the various textures and organs, that the discovery of that structure opens the most direct road to the determination of their uses. That kind of anatomy which investigates structure with a special view to function may be properly designated *Physiological Anatomy*.

A correct physiology must ever be the foundation of rational medicine. He who is ignorant of the proper construction of a watch, and of the nature of the materials of which it is made, could not find out in what part its actions were faulty, and would therefore be very unfit to be entrusted with repairing it. In medicine, the first step towards the cure of disease is to find out what the disease is and where it is situate (*diagnosis*). Without a knowledge of the offices which various parts fulfil in the animal economy, our search to determine what organ or function is deranged must be most vague and indefinite. *Pathology* is the physiology of disease; and it is obvious, that no pathological doctrines can command confidence, which are not founded upon accurate views of the natural functions. It is also certain that improvements in pathology must follow in the wake of an advancing physiology.

The practice of medicine and surgery abounds with examples, illustrating the immense benefits which physiology has conferred upon the healing art. The great advance which has been made

of late years in the pathology of nervous diseases, is mainly owing to the discoveries of Bell, and many others, in the functions of various nerves, and the general doctrines of nervous actions. We may instance the case of the facial nerve—the portio dura of the seventh pair. It was supposed formerly that this nerve was the seat of that painful disease, called *tic douloureux*, and section of it has been performed for the relief of the patient. It is now known that this nerve could not be the seat of a very painful disease, for it is itself, in a very great degree, devoid of sensibility. It need hardly be added, that the operation is discarded.

The dangerous disease, to which many children have fallen victims, *laryngismus stridulus* or *crowing inspiration*, although admirably described by practical physicians, was never properly understood until the functions of the laryngeal nerves were clearly ascertained, and until it had been shown that spasmodic actions may be excited by irritation of a remote part, or through a stimulus reflected from the nervous centre. It is now known, that this disease has not its seat in the larynx, where those spasms occur which excite so much alarm for the fate of the little patient; but that it is an irritation of a distant part, which derives its nerves from the same region of the cerebro-spinal centres with the larynx,—that the afferent nerves of that part convey the irritation to the centre, whence it is reflected by certain efferent nerves to the muscles of the larynx.

The accurate diagnosis of diseases of the heart rests entirely upon a correct knowledge of the physiology of that organ. This improvement in medicine may be said to date from the time of Harvey, for he was the first who clearly expounded the mechanism of the central organ of the circulation. But the application of auscultation to the exploration of the sounds developed in its action, and the correct interpretation of those sounds in health by the experiments and observations of the last few years, have almost completely removed whatever difficulties stood in the way of the detection of cardiac maladies.

We are not less indebted to the illustrious Englishman, who discovered the circulation of the blood, for having paved the way to a rational treatment of aneurismal and wounded arteries by the modern operation of placing a ligature between the heart and the seat of the disease or injury. "The active mind of John Hunter," says Mr. Hodgson, "guided by a deep insight into the powers of the animal economy, substituted for a dangerous and unscientific operation, an improvement founded upon a knowledge of those laws which influence the circulating fluids and absorbent system; and few of his brilliant discoveries have contributed more essentially to the benefit of mankind."

In investigating the functions of the human body, the physiologist cannot do better than follow the instructions laid down by Haller in the preface to his invaluable work, "Elementa Physiologiæ Corporis Humani."

The first and most important step towards the attainment of physiological knowledge, is the study of the fabric of the human body.

"Et primùm," says Haller, "cognoscenda est fabrica corporis humani, cujus penè infinitæ partes sunt. Qui physiologiam ab anatome avellere studuerunt, ii certè mihi videntur, cum mathematicis posse comparari qui machinæ alicujus vires et functiones calculo exprimere suscipiunt, cujus neque rotas cognitas habent, neque tympana, neque mensuras, neque materium."

A knowledge of human anatomy alone is, however, not sufficient to enable us to form accurate views of the functions of the various organs. Before an exact judgment can be formed of the functions of most parts of living bodies, Haller says, that the construction of the same part must be examined and compared in man, in various quadrupeds, in birds, in fishes, and even in insects. And, in proof of the value which attaches to this knowledge of *comparative anatomy*, he shows how, from that science, it may be determined that the liver is the organ which secretes bile; and that the bile found in the gall-bladder is not secreted by, but conveyed to, that organ: for no animal has a gall-bladder without a liver, although many have a liver without a gall-bladder; and, in every case where a gall-bladder is present, it has such a communication with the liver, that the bile secreted by the latter may be easily transferred to the former. "Vides adeò," he adds, "bilem hepate egere, in quo paretur, vesiculà non egere, non ergo in vesiculâ nasci, ex hepate verò in vesiculum transire."

And Cuvier has happily compared the examination of the comparative anatomy of an organ, in its gradation from its most complex to its simplest state, to an experiment which consists in removing successive portions of the organ, with a view to determine its most essential and important part. In the animal series we see this experiment performed by the hand of nature, without those disturbances which mechanical violence must inevitably produce. We thus learn, from comparative anatomy, that the vestibule is the fundamental part of the organ of hearing; and that the other portions, the semicircular canals, the cochlea, the tympanum and its contents, are so many additions made successively to it, according as the increasing perceptive powers of the animals render a more delicate acoustic organ necessary. In a similar manner we learn, that one portion of the nervous system, in those animals in which it has a definite arrangement, is pre-eminently associated with the mental principle, and is connected with, and presides over, the other parts. This organ, the brain, is always situate at the anterior or cephalic extremity of the animal, and with it are immediately connected the organs of the senses, the inlets to perception. We soon find that the brain exhibits a subdivision into distinct parts; and of the relative importance of these parts, and their connection with the organs of sense, and with the intellectual functions, we derive the most important information from the study of comparative anatomy.

Haller further assigns the examination of the living animal as a valuable aid in physiological research. Doubtless, many obscure points have been elucidated by experiments on living animals, and discoveries have been made which have greatly contributed to the

progress of physiology; but the best physiologists are ever reluctant to interrogate nature in this way, knowing that replies elicited by torture are rarely to be depended upon. Very useful knowledge may be derived from observing the play of certain functions in living animals, or in Man himself,—contrasting them in various individuals, and noting the effects of age, sex, and temperament, and ascertaining the influence which other conditions, natural or artificial, may exert upon them.

The investigation of disease, both during life and after death, is of great value to enable us to appreciate the action of an organ in health. If, for example, as Haller remarks, a particular function be ascribed to a certain part, how can there be a more favourable opportunity of testing the accuracy of such a doctrine than by the examination of a body in which that part was affected with a disease, of which the previous history was known? If the function in question had been vitiated, or destroyed, it may be fairly presumed to have had its seat in the diseased organ. Nothing has contributed more largely to determine the functions of particular nerves, than exact histories of the symptoms during life, in cases in which they had been found, after death, in a diseased condition.

For exploring the minute structure of various textures, the anatomical elements of the body, Haller advises the use of the *Microscope*. The great improvements which modern opticians have accomplished, not only in the dioptric but also in the mechanical adjustments of this instrument, render it an invaluable adjuvant in physiological research. We shall have frequent occasion in the following pages to refer to anatomical analyses, effected by the microscope, of the utmost value to the knowledge of function. It may, however, be remarked, that, as the sources of fallacy are numerous even with the best instruments, more depends upon the observer himself, in this kind of investigation, than in almost any other.

The great impediment to deriving correct inferences from microscopical observations has arisen from the discordance, too apparent, in the narrations of different observers. This discordance has been the result of a twofold cause; namely, imperfection of the instruments, and the very unequal qualifications of different observers. The former cause is now almost completely removed; the latter must remain, while men imperfectly appreciate their own abilities for particular pursuits.

To make microscopical observation really beneficial to physiological science, it should be done by those who possess two requisites: an *eye*, which practice has rendered familiar with genuine appearances as contrasted with those produced by the various aberrations to which the rays of light are liable in their passage through highly refracting media, and which can quickly distinguish the fallacious from the real form; and a *mind*, capable of detecting sources of fallacy, and of understanding the changes which manipulation, chemical reagents, and other disturbing causes may produce in the arrangement of the elementary parts of various textures.

To these we will add another requisite, not more important for

microscopical than for other inquiries; namely, a freedom from preconceived views or notions of particular forms of structure, and an absence of bias in favour of certain theories, or strained analogies. The history of science affords but too many instances of the baneful influence of the *idola specûs* upon the ablest minds; and it seems reasonable to expect that such creatures of the fancy would be especially prone to pervert both the bodily and the mental vision, in a kind of observation which is subject to so many causes of error, as that conducted by the aid of the microscope.

Finally, the sagacious Haller perceived how necessary to the furtherance of physiology is a knowledge of *Organic Chemistry;* and we could adduce many instances to prove, that the attention, which has of late years been paid to this subject, has not been without its fruit, in giving us an insight into the nature of many functions, which, without it, we could not have obtained.

In the living body the most delicate chemical processes are unceasingly going on, for the formation of new compounds and the destruction or alteration of old ones. It is evident that no progress can be made in the investigation of these invisible processes, unless we can arrive at an exact knowledge of the chemical composition of the various substances which are employed in them.

Henceforward, in physiological research, anatomical and chemical analysis must go hand in hand: the former to ascertain the minute mechanism of the various processes; the latter, to determine the nature of the affinities by which the syntheses and analyses of the living laboratory are effected.

In the composition of the preceding chapter we have to acknowledge valuable aid derived from the following works:—Haller, Elementa Physiologiæ Corporis Humani; Barclay on Life and Organization; Roberton on Life and Mind; Prichard on the Doctrine of a Vital Principle; Dr. Carpenter's article Life, and Dr. Alison's article Instinct, in the Cyclopædia of Anatomy and Physiology; Remarks on Skepticism, by the Rev. Thomas Rennell; Daniell's Chemistry; Graham's Chemistry.

CHAPTER I.

SOLID AND FLUID CONSTITUENTS OF ANIMAL BODIES.—PROXIMATE PRINCIPLES.—SECONDARY ORGANIC COMPOUNDS.—CLASSIFICATION OF THE TISSUES.—DEVELOPMENT OF THE TISSUES FROM CELLS.—PROPERTIES OF THE TISSUES.

ANIMAL bodies are composed of solids and fluids. The former constitute the various textures and viscera; the latter, the blood, lymph, chyle, and the liquid secretions of glands, contained either in their excretory ducts or in special reservoirs.

The solid textures contain only about one-fourth of solid matter, the rest is water. The great shrinking which they experience, when dried, shows how much of their bulk they owe to this combination;

and parts thus shrunken swell out again, and assume their natural condition on the addition of water. The mummy of a large man is of a very trifling weight. Blumenbach possessed the entire *perfectly dry* mummy of a Guanche or aboriginal inhabitant of Teneriffe, presented to him by Sir Joseph Banks, which, with all its muscles and viscera, weighed only seven pounds and a half.

Water is one of the most important constituents of animal bodies. It forms four-fifths of their nutrient fluid, the blood; and it gives more or less of flexibility and softness to the various solid textures. The loss of it in great quantity speedily puts a stop to vital action, as may be easily shown in the lower animals; and some animalcules, in which all appearance of life may have ceased on being deprived of it, will revive on its being supplied to them again. It is a solvent of many organic matters; some also are suspended in it: it is, therefore, a valuable medium for conveying these substances to the several textures and organs. It plays a most important part in the various chemical operations of the body; and its addition to, or subtraction from a particular compound is capable of converting it into a substance of very different properties.

By anatomico-physiological analysis we separate the solids and fluids of the body into their various kinds, and classify and arrange them according to their characters and properties.

By chemical means we obtain from them a class of substances, called *proximate principles*, substances but one step removed from the organized tissue, some of which are held in solution in the blood. These, in combination with sulphur, phosphorus, and other simple substances (incidental elements), and salts, form the material out of which the organized tissues are framed.

The general chemical constitution of these proximate principles has already been discussed in the Introduction; and they have been distinguished from another class of organic substances, *the secondary organic compounds*, among which we must particularize those which are formed by chemical action in the living organism, from materials furnished by it. These are found in various secreted fluids, and are easily obtained from them, either by spontaneous separation, or by simple chemical means; and they must not be confounded with a vast variety of compounds, which the chemist can create at will both from them and from the proximate principles, through the affinities of various chemical substances for them.

The following table contains a list of substances which, in the present state of our knowledge, may be properly assigned to the two classes of organic compounds, to which allusion has been made:

PROXIMATE PRINCIPLES.	SECONDARY ORGANIC COMPOUNDS.
Albumen, Fibrine, Caseine, } Compounds of Proteine.	Urea; Uric or Lithic acid; } in the Urine.
Gelatine.	Cholesterine; in the Bile.
Chondrine.	Biliary matters.
Elaine.	Pepsine; in the Gastric Juice.
Stearine.	Sugar of milk.
Margarine.	Lactic acid.
Hæmatosine.	
Globuline.	

According to Mulder, this principle yields the following elements in one hundred parts:

Nitrogen	15·83
Carbon	54·84
Hydrogen	7·09
Oxygen	21·23
Phosphorus	0·33
Sulphur	0·68
	100·00

2. *Fibrine.*—This proximate principle forms the basis of the muscles; and is, therefore, the chief constituent of the flesh of animals, in which it is found in the solid form. It exists in a state of solution, in the serum of the blood, forming, with that fluid, the *liquor sanguinis* of Dr Babington, in the lymph, and in the chyle. It is a constituent of the exudation (coagulable lymph) which forms on certain surfaces, as the result of the inflammatory process, and it sometimes occurs in dropsical fluids.

Fibrine is distinguished from the other proximate principles, by its remarkable property of *spontaneous coagulation.* When blood is drawn from a vein, and allowed to rest, it speedily separates into a solid portion, the *crassamentum* or *clot*, and a fluid portion, the *serum.* The former consists of fibrine, with the red particles entangled in it during its coagulation. It sometimes happens, that, owing to an unusual aggregation of the red particles together, and to their more speedy precipitation, a portion of fibrine on the surface coagulates without enclosing the colouring matter. A yellowish-white layer forms the upper stratum of the crassamentum, and this is called the *buffy coat* or *inflammatory crust.* It is an example of nearly colourless fibrine, but contains also peculiar globules.

We may obtain fibrine in a state of considerable purity, by cutting the crassamentum into slices, and washing them in clean water so as to dissolve out the colouring matter; or by briskly stirring, with a bundle of twigs, blood as it flows from a vein: the fibrine coagulates upon the twigs in small portions, which, being washed, afford good specimens of colourless fibrine; by digesting afterwards in alcohol and ether, the adhering impurities are got rid of. Another mode of obtaining this substance is that suggested by Müller, namely, to filter frogs' blood, the red particles of which being too large to permeate the pores of the filter, the liquor sanguinis passes through in a colourless state, and its fibrine coagulates free from colouring matter. Sometimes we obtain masses of fibrine, great part of which is colourless, from the cavities of the heart, and from the large arteries, after death. It is also accumulated, and disposed in a peculiar lamellar form, in the sacs of old aneurisms.

Pure fibrine is white, tasteless, and inodorous; it tears into thin laminæ, which are transparent, and it is remarkably elastic; by drying, it becomes yellow, hard, and brittle, and loses three-fourths of its weight, but imbibes water again when moistened: it is insoluble in both hot and cold water, in alcohol, and in ether. By long-continued boiling in water, its composition is changed, and it becomes

soluble. Strong acetic acid converts it into a jelly-like mass, which is sparingly soluble in water. All the alkalies dissolve fibrine. Any of these solvents of fibrine will prevent the coagulation of blood, which has been allowed to drop into it as it flows from the blood-vessels.

Fibrine is dissolved by cold concentrated muriatic acid, and, if kept at a cool temperature for twenty-four hours, the solution acquires an indigo-blue colour. Albumen, similarly treated, assumes a violet colour.

Caustic potash, common salt, carbonate of potash, and many neutral salts, when mixed in certain quantities with the blood, have the property of preventing the coagulation of its fibrine.*

We subjoin the ultimate analysis of fibrine, as given by Mulder. In one hundred parts, he found

Nitrogen	15·72
Carbon	54·56
Hydrogen	6·90
Oxygen	22·13
Phosphorus	0·33
Sulphur	0·36
	100·00

3. *Caseine.*—This principle has many properties in common with albumen and fibrine. It is found abundantly in milk; its occurrence in other fluids has not been positively determined. The curd, which is formed by heating milk in which a free acid existed, consists of a combination of caseine with the acid. Heat alone will not effect the precipitation of the curd; but the addition of a little acid of any kind will occasion it.

When dilute sulphuric acid is added to skimmed milk, a precipitate occurs, which is sulphate of caseine. By digesting the clot, thus formed, with water and carbonate of lime, the acid combines with the lime, and the caseine, set free, dissolves in the water, and may be obtained by evaporation.

Caseine is coagulated very perfectly by the action of rennet (the fourth or true digesting stomach of the calf) aided by heat. This power of coagulating caseine is not to be attributed to the acid of the calf's stomach, but to the organic principles (pepsine) resident in it; for the power remains after all evidence of acid reaction has been removed. This is one of the most powerful agents in causing the coagulation of caseine, and it has been employed in domestic economy for the manufacture of cheese, which consists of the curd mixed with butter, compressed and dried. So perfect is the coagulating power of rennet, that not a particle of caseine in milk submitted to its action will remain uncoagulated.

Caseine comports itself with reagents in a manner very similar to albumen. In the coagulated state it is insoluble in water, but soluble in liquor potassæ. It is not precipitated by heat alone, in which respects it differs from albumen. Acetic acid, which will not precipi-

* See further observations on the results of the examination of fibrin by the microscope, in the chapter on the Blood.

tate albumen, causes the coagulation of caseine, and an excess again dissolves it.

Caseine contains sulphur, but no phosphorus.

Mulder's ultimate analysis is as follows:

Nitrogen	15·95
Carbon	55·10
Hydrogen	6·97
Oxygen	21·62
Sulphur	0·36
	100·00

If albumen, or fibrine, or caseine be dissolved in a moderately solution of caustic potash, and exposed for some time to a hig perature, it becomes decomposed; and if acetic acid be now a precipitate takes place of a gelatinous translucent matter. substance was discovered by Mulder, and named by him P (from the Greek verb πρωτευω, I am first), as being the radicle c proximate principles; or, in the language of Liebig, the comı ment and starting-point of all the tissues; so that it appears th of these principles is composed of this substance, with the a of certain proportions of phosphorus, sulphur, or of both. process by which it is obtained, the object is to remove the and phosphorus and any salts which may be mixed with it, an the proteine free.

Proteine, when dried, forms a hard, brownish-yellow sub without taste, and insoluble in water and alcohol. It attracts m from the air, and swells out again into a gelatinous mass when ened. It is soluble in all acids, when diluted; and forms co tions with them, which are with difficulty, or not at all, sol excess of acid. It is also dissolved in dilute alkalies, or in sc of alkaline earths.

The ultimate analyses of proteine, according to Mulder, fro hundred parts gives as follows:

Nitrogen	16·01
Carbon	55·29
Hydrogen	7·00
Oxygen	21·70
	100·00

The following table exhibits the relations which albumen, and caseine bear respectively to proteine:

Albumen of serum	= 10 eqts. Proteine + 1 eqt. Phosph. + 2 eqts. Sul
Albumen of Egg	= 10 eqts. Proteine + 1 eqt. Phosph. + 1 eqt. Sul
Fibrine	= 10 eqts. Proteine + 1 eqt. Phosph. + 1 eqt. Sul
Caseine	= 10 eqts. Proteine + 1 eqt. Sulph.

Besides the essential elements of these proximate principles, are obtained by their ultimate analysis, we find certain salts with them. In albumen, phosphates and sulphates of eart alkalies and chloride of sodium; in fibrine, phospate of lime; caseine, the same salt, in the proportion of 6·24 per cent. phosphate of lime is the same as bone-earth, the existence (

union with the proximate principle, which forms the chief constituent of milk, seems to have reference to the process of ossification during the growth of the infant.

Proteine, in every respect the same as that which forms the basis of the proximate principles just described, may be obtained from similar elements in the vegetable kingdom. Gluten, which exists abundantly in the seeds of the Cerealia, yields a principle which is called *vegetable fibrine;* the same substance coagulates spontaneously in the newly expressed juice of vegetables. From the clarified juices of cauliflower, asparagus, mangel-wurzel, or turnips, when made to boil, a coagulum is formed, which cannot be distinguished from the coagulated albumen of serum or the egg. This is *vegetable albumen.* And in peas, beans, lentils, and similar leguminous seeds, we find a substance similar to caseine. It is *vegetable caseine*, which, like the animal principle of the same name, does not coagulate by heat alone, but yields a coagulum on the addition of an acid, as in milk. "The chemical analysis of these three substances," says Liebig, "has led to the very interesting result, that they contain the same organic elements, united in the same proportions by weight; and, what is still more remarkable, that they are identical in composition with the chief constituents of blood, animal fibrine, and albumen. They all three dissolve in concentrated muriatic acid with the same deep purple colour; and, even in their physical characters, animal fibrine and albumen are in no respect different from vegetable fibrine and albumen. It is especially to be noticed, that by the phrase identity of composition, we do not here imply mere similarity; but that, even in regard to the presence and relative amount of sulphur, phosphorus and phosphate of lime, no difference can be observed."

4. *Gelatine.*—This substance exists in a peculiar combination with the tissues of which it forms a constituent, and can only be obtained by artificial means. If the cutis or true skin, tendon, or bone, be subjected to continued boiling, this substance is obtained in solution in the hot water, and upon cooling assumes the form of a solid jelly, which is the more solid as the quantity of water contained in it is less. The textures which yield gelatine are, the white fibrous tissue, areolar tissue, skin, serous membranes, bone. Glue prepared from hides, &c.; size from parchment, skin, &c.; and isinglass from the swimming bladder of the sturgeon, are various forms of gelatine used in commerce.

Gelatine, obtained by boiling, is in combination with a considerable quantity of water: by a slow and gentle heat this may be driven off, and the gelatine obtained in a dry state. Dry gelatine is hard, transparent, colourless, without smell or taste, of neutral reaction; in cold water it softens and swells up, and dissolves in warm water. It is insoluble in alcohol and ether, but very soluble in the dilute acids and alkalies. When tannin, or the tincture or infusion of galls, is added to its solution in water, a brownish precipitate is thrown down —the *tanno-gelatine*, which may be precipitated from a solution of gelatine in 5000 times its weight of water.

The process of tanning leather results from the affinity of gelatine

for tannin. The skins of the animals having been first freed from cuticle and hairs by soaking in lime-water, are tanned by submitting them to the action of infusion of oak-bark, the strength of which is gradually increased until a complete combination has taken place. An insoluble compound is thus formed, capable of resisting putrefaction.

According to Mulder, gelatine contains in one hundred parts,

Nitrogen	18·350
Carbon	50·048
Hydrogen	6·477
Oxygen	25·125
	100·000

to which may be added some inorganic material, chiefly phosphate of lime.

Dr. Prout remarks, the gelatine in animals may be said to be the counterpart of the saccharine principles of plants; it being distinguished from all other animal substances by its ready convertibility into a sort of sugar, by a process similar to that by which starch may be so converted. If a solution of gelatine in concentrated sulphuric acid be diluted with water and boiled for some time, gelatine-sugar may be obtained from it, on saturating with chalk. Again, by boiling gelatine in a concentrated solution of caustic alkali, it is separated into *leucine* and gelatine sugar, or *glycicoll*. The latter product crystalizes in pretty large rhomboidal prisms; is colourless, inodorous, and very sweet. (*Graham's Chemistry*, p. 1039. [Am. Ed., p. 700.]) It differs from sugar, however, in the important particular, that it contains nitrogen; and Mulder assigns to it the following formula, $C_8 H_7 N_2 O_5 + 2\ HO$.

Proteine cannot be obtained from gelatine; but it seems reasonable to infer, that it or its compounds must have contributed to the formation of the latter substance, for, in the egg, the gelatine of the chick cannot be derived from any other material than a compound of proteine. Scherer has shown that gelatine contains the elements of two equivalents of proteine, with three of ammonia, and seven of water.

5. *Chondrine* is a substance in many respects similar to gelatine. It is obtained in a state of solution, by boiling water, from the permanent cartilages and from the cornea; also from the temporary cartilage prior to ossification; it gelatinizes on cooling, and when dry assumes the appearance of glue. It differs from gelatine, in not being precipitated by tannin, and in yielding precipitates to acetic acid, alum, acetate of lead, and the protosulphate of iron, which do not disturb a solution of gelatine. It resembles the proteine compounds in containing a minute quantity of sulphur.

Mulder's analysis of one hundred parts is,

Nitrogen	14·44
Carbon	49·96
Hydrogen	6·63
Oxygen	28·59
Sulphur	0·38
	100·00

Respecting the remaining substances included in the list of true proximate principles, very few words are necessary, as they will be more fully treated of in subsequent chapters.

Elaine, *Stearine*, and *Margarine* are proximate principles of fat, and are found also in the brain and nerves. Stearine exists but sparingly, or not at all, in human fat.

Hematosine and *Globuline* are the constituents of the particles, or corpuscles, to which the blood owes its colour. They are both nearly allied to albumen, and the latter is regarded as a compound of proteine.

The proximate principles which have been described in the preceding paragraphs are constituents of the animal food, upon which the human race, and the inferior creatures, to a great extent, subsist; and the discovery that similar principles exist in the vegetable kingdom, also adapted for food, is of the highest interest, as proving that both kingdoms of organized nature are capable of affording the materials which are suited to supply the waste in the animal tissues which is the necessary result of their vital actions. The blood is the immediate *pabulum* of the tissues; its composition is nearly or entirely identical with them; it is, indeed, as Bordeu long ago expressed it, liquid flesh; it contains the elements of the solids in a state of solution —*le sang est de la chair coulante.* The proteine compounds more immediately contribute to the formation of the blood, and, as we have seen, may be obtained directly from that fluid; and the process of nutrition consists in the attraction of certain of these principles from the blood, and the appropriation of them by the textures and organs, in a form assimilated to that of their elementary parts.

It is necessary to the support of nutrition, that these proximate principles should be supplied in proper quantity to the blood, from time to time, together with a due proportion of water; and as the human body is composed of a variety of textures, differing in their chemical composition, so a variety of food is required for its perfect nourishment. This statement, which appears most reasonable prior to experience, is fully borne out by the results of the various experiments on the nutritive power of different substances, from the time of Papin to the present day. No one proximate principle is of itself adequate to support life: if any such substance be administered alone to animals, they will perish sooner or later, with signs of waste and destruction in various textures. This had been long ago ascertained respecting gelatine; but a commission appointed by the French Academy have lately reported that it applies equally to albumen, caseine, or fibrine, if employed alone; and that neither animals nor man should be restricted to any course of diet, which does not contain *all* the proximate elements of their frame.

These facts should be made known to, and impressed upon all, whose position in society leads them to superintend the administration of food to a number of human beings congregated in prisons, workhouses, or other public institutions. A complex machine, made up of many different kinds of substances, requires for its repair a corresponding variety of materials. The fabric of man's body is a piece

of mechanism compounded of divers parts, derived from albumen fibrine, gelatine, &c.; and the material, which is to supply the wear and tear that continually go on in it, ought to contain these substances. It is even more important for sufficient nourishment that attention should be paid to the *quality* than to the quantity of the food administered.

By the function of digestion, a fluid (*the chyle*) is prepared, which contains those constituents of the food that are adapted to nourish the body, and the first step of the nutrient process consists in the addition of this new supply of nutritious material to the blood. A further stage of this process is that whereby the several proximate principles are separated in order to be applied to the support of their appropriate textures; as albumen, to the albuminous tissues; fibrine, to the fibrinous. These two principles have already appeared in the chyle, and pass with it into the blood-vessels, in which all the changes necessary to nutrition take place. It is probable that gelatine is formed in the blood, but is attracted from it by its proper tissues immediately upon its formation, so that it does not accumulate in it; and this accounts for our not being able to find it in the blood. The fatty elements also separate in the blood, and are destined to nourish the adipose tissue, and the nerves. It may be fairly conjectured that the development and separation of these principles take place in the capillary blood-vessels, because those vessels penetrate and play freely among the elementary parts of the tissues; and also because the blood does not manifest a decided change in its characters until it has passed through that part of the sanguiferous system.

The blood is likewise the seat of other changes, not less important to the well-being of the animal economy. As certain particles of the various tissues become effete and useless, they are removed either by a direct absorbing power of the blood-vessels, or by that of certain vessels, called lymphatics, and thus they again find their way into the current of the circulation. Here the elements of the tissues, by some unknown chemical agency, undergo certain transformations, and the *secondary compounds* are formed, to be excreted from the system by means of particular organs. Urea and uric acid, thus formed in the blood, are excreted by the kidneys; lactic acid, by the kidneys and the skin; the elements of the bile, by the liver, &c., &c. But whilst it is highly probable that the effete particles furnish materials for these compounds, there seems good reason to believe, that, at least with respect to some of them, the food likewise contributes immediately to their formation. That this is the case with respect to the bile, is rendered very likely by several circumstances which cannot be dwelt upon at present.

In the present state of our knowledge it is impossible to assign the particular tissues whose metamorphoses give rise to the formation of certain *secondary* compounds. Dr. Prout has expressed the opinion that urea is derived from the gelatinous, and uric acid from the albuminous tissues. And it may be conjectured that the fatty tissues afford material for the formation of some of the constituents of the bile.

As each of these secondary organic compounds forms a component

part of some special secretion, it would be premature to do more at present than allude to them; we, therefore, postpone the further investigation of them to those parts of the work where the respective secretions will be treated of.

Classification and properties of the tissues.—From the proximate principles, the various textures are produced by the development of particular organic forms. It has already been stated, that the simplest form which animal matter assumes in its organization is that of a nucleated cell. Such cells exist in vast numbers, free and isolated, floating in the blood, but having occasionally a remarkable tendency to cohere. These are the red particles of the blood, which perform some very important office in reference to that fluid and the different tissues, as appears from the serious results consequent upon a great deficiency of them. They may be considered to be among the simplest products of organization.

In the embryonic state all the tissues are composed of cells, analogous in structure to the corpuscles of the blood. These are united together by a more or less abundant intercellular substance, which is either homogeneous (*hyaline*), minutely granular, or indistinctly fibrous. Some tissues retain, as their permanent character, this cellular structure; whilst in others the cells undergo certain metamorphoses by which they are converted into other forms, which constitute the anatomical elements of the adult textures.

It seems impossible to devise a satisfactory arrangement of the tissues, which shall be based on one principle of classification. The following table has been constructed chiefly with the object of presenting to the reader a general view of the various tissues, the anatomical characters of which will be discussed in subsequent pages.

TABULAR VIEW OF THE TISSUES OF THE HUMAN BODY.

1. Simple membrane, homogeneous, or nearly so, employed alone, or in the formation of compound membranes.	Examples.—Posterior layer of the Cornea.—Capsule of the lens.—Sarcolemma of muscle, &c.
2. Filamentous tissues, the elements of which are real or apparent filaments.	White and yellow fibrous tissues.—Areolar tissue.
3. Compound membranes, composed of simple membrane, and a layer of cells, of various forms (epithelium or epidermis), or of areolar tissue and epithelium.	Mucous membrane.—Skin.—True or secreting glands.—Serous and synovial membranes.
4. Tissues which retain the primitive cellular structure as their permanent character.	Adipose tissue.—Cartilage.—Gray nervous matter.
5. Sclerous or hard tissue.	Bone.—Teeth.
6. Compound tissues.	
a. Composed of tubes of homogeneous membrane, containing a peculiar substance.	Muscle.—Nerve.
b. Composed of white fibrous tissues and cartilage.	Fibro-cartilage.

The first texture enumerated in this table is an example of the simplest form of membrane. Its principal character is extension; but as to the arrangement of its ultimate particles nothing is known, for under the highest powers in the microscope it appears homogeneous, that is, without visible limits to its particles, or, at most, irregularly and very indistinctly granular. The capsule of the lens, the

posterior layer of the cornea, and the walls of the primary organic cells, are composed of it; and it is employed in forming muscle, nerve, and the adipose and tegumentary tissues.

The filamentous tissues are extensively used for connecting different parts, or for associating the elements of other tissues. The ligaments of joints, for instance, are composed of the white or yellow fibrous tissues; and areolar tissue surrounds and connects the elementary parts of nerves and muscles, accompanies and supports the blood-vessels, and unites the tegumentary tissues to their subjacent parts or organs.

Under the title *compound membranes* we include those expansions, which form the external integument of the body, and are continued into the various internal passages, which, by their involutions, contribute to form the various secreting organs or glands. These are composed of the simple homogeneous membrane covered by epidermis or epithelium, and resting upon a layer of vessels, nerves, and areolar tissue in great variety; and they constitute the skin and mucous membranes, with the various glandular organs which open upon their surface. Hairs and nails, being hardened cuticle, are justly regarded as appendages to the former.

To these we may add those remarkable membranes, composed of areolar tissue and a thin indusium of epithelium, which are employed as mechanical aids to motion. These are the serous membranes which line the great cavities of the body, and the synovial membranes, which are interposed between the articular extremities of the bones in certain joints, or are connected with and facilitate the motions of tendons.

The tissues which compose the fourth class have no common character, except their adherence, in the adult state, to the primitive cellular structure, and their analogy in that particular with the vegetable tissue. Although a certain agreement, in morphological characters, allows these textures to be grouped together, none can be more dissimilar as regards their vital endowments. They differ materially as to the degree of cohesion between their cells: in cartilage there is generally a firm and resisting intercellular substance; in adipose tissue, the interval between the cells is occupied by areolar tissue and blood-vessels, which are foreign to the true adipose cells; and, in the gray nervous matter, vessels and nerve tubes exist between the cells.

The sclerous tissue (σκληρος, hard), contains a large proportion of inorganic material, to which it owes its hardness; it differs very materially from all the other tissues, excepting cartilage and fibro-cartilage, which, as regards hardness, might be classed with it.

The compound tissues are those, the elementary parts of which are made up of two distinct tissues. Thus both muscle and nerve are composed of parallel fibres or threads, each fibre being compound; in muscle, it is composed of homogeneous membrane, disposed like a tube, containing a fleshy (*sarcous*) substance, arranged in a particular manner, which is the seat of the vital properties of the tissue; and, in nerve, the fibres are composed of similar tubes of homogeneous membrane containing an oleo-albuminous substance, *neurine*.

Fibro-cartilage is also properly a compound texture, being made up of white fibrous tissue and cartilage; it is employed almost exclusively in the mechanism of the joints of the skeleton, in which it is associated with bone, cartilage, and ligaments.

Of the development of the tissues from cells.—At the earliest period of embryonic life, the process of organization has advanced to so slight an extent, that the variety of textures above described has not yet appeared.

The prevailing mode, in which the development of animals takes place, is by the formation, within the parent, of a body containing the rudiments of the future being, as well as a store of nutrient material sufficient to nourish the embryo for a longer or shorter period. This body is called the *ovum* or egg. It is of that form which, in a former page (p. 32, fig. 1), has been described and delineated as the simplest which organization produces. It consists of a vesicular body filled by a fluid, and enclosing another, within which is a third, consisting of one or more minute, but clear and distinct granules. The first, or the *vitelline* membrane of the ovum, is the wall of a cell; it is composed of homogeneous membrane: the second, or the *germinal vesicle* of the egg, is the nucleus of the first: and the third, which is called by embryologists the *germinal spot*, is a *nucleolus* to the second. It appears, from the researches of Wagner and Barry, that the nucleus or germinal vesicle precedes the formation of the vitelline membrane, but the precise relation as to the period of its formation of the nucleolus or germinal spot to the nucleus has not yet been satisfactorily made out. The germinal vesicle and spot become the seat of a series of changes, which give rise to the development of new cells, for the formation of the embryo.

At this period the embryo consists of an aggregate of cells, and its further growth takes place by the development of new ones. This may be accomplished in two ways: first, by the development of new cells within the old, through the subdivision of the nucleus into two or more segments, and the formation of a cell around each, which then becomes the nucleus of a new cell, and may in its turn be the parent of other nuclei; and, secondly, by the formation of a granular deposit between the cells, in which the development of the new cells takes place. The granules cohere to each other in separate groups here and there, to form nuclei, and around each of these a delicate membrane is formed, which is the cell-membrane. The nuclei have been named *cytoblasts*, because they appear to form the cells (κυτος, cell; βλαστεω, to produce); and the granular deposit in which these changes take place is called the *cytoblastema*.

In every part of the embryo, the formation of nuclei and of cells goes on in one or both of the ways above-mentioned; and, by and by, ulterior changes take place, for the production of the elementary parts of the tissues. The precise share which the cells take in this process cannot be made intelligible in the present stage of our inquiry, even if observers were agreed in their accounts of the phenomena. It must suffice for us now to explain, as far as we are able, the general changes

that occur, and the probable office which each part of the cell performs in them.

The changes which the cells undergo in the formation of the tissues, may be described under two heads; first, those affecting the cell-membrane; and, secondly, those in which the nucleus is concerned. In those tissues, whose ultimate elements are fibrous, that is, consisting of real or apparent fibres, as areolar and fibrous tissues, the cell-membranes become elongated, and so folded or divided as to give the appearance of a subdivision into minute threads or fibres. In the tissues, which are composed of tubes of homogeneous membrane containing a peculiar substance within them, as muscle and nerve, the cells are joined end to end, and, the partitions at each extremity being removed, their cavities communicate, so that they together form a tube, or sheath, in which the deposit of the proper muscular or nervous substance takes place. The smallest or capillary blood-vessels also are formed by the coalescence of the walls of the cells, not at one or two, but at several points, owing to their elongation, here and there, into pointed processes, which unite and form the ramifications of the vessels.

In these examples, the nucleus of the cell appears to take no part in the formation of the tissue. What becomes of it? does it become absorbed, or does it waste away, its office having ceased? There is abundant evidence to show that the nuclei are still persistent in the fully-formed tissues, for they have been seen in all those enumerated in the last paragraph. They are generally altered in form, being flattened and elongated. Henle believes that, while they retain their peculiar characters, they are prolonged at either pole into peculiar fibres, distinct, in anatomical and chemical characters, from the proper fibres of the tissue; he designates the latter *Zellenfasern*, cell-fibres; and the former *Kernfasern*, nucleus fibres. For instance, the two elements of areolar tissue, which will be described at a future page, are derived, according to him, the white fibrous element, from the cell; the yellow, from the nucleus. The formation of the homogeneous simple membrane which forms the basement of the skin and mucous membrane, may be ascribed to the flattening and fusion of the cell-walls into one another. The free surface of these membranes, wherever they may be found, whether as integuments to the body, or folded into glands, is the seat of a continual development of new cells, which may have primarily sprung from the nuclei of the formative cells of the basement membrane.

In other tissues the walls of the cells become thickened by a deposition around and between them, with which they become united and incorporated, and thus an intercellular substance is formed. This substance becomes the seat of a further deposition, or new arrangement of particles, which, as far as we know at present, is not preceded by the development of cells. In cartilage, which in its simplest state is only an aggregate of cells, this substance assumes a fibrous form. In most textures, it is not improbable that the nuclei are persistent; in cartilage, they remain in the cell-cavities, and possibly contribute to the growth and nutrition of the cartilage; in bone, they form the

lacunæ from which minute canals are prolonged into neighbouring ones, or into the vascular channels; and, in teeth, they are probably converted into the dental tubuli.

From the preceding brief and necessarily imperfect sketch, it seems evident that, in the various metamorphoses of the fœtal into the perfect tissues, both the elements of the cells take a part. In no instance does there appear to be an actual conversion of either cell-wall or nucleus into the ultimate elements of the tissues. The cell-walls may be changed into a part, *accessory* to the complete texture, as the sarcolemma or sheath of the muscular fibre; but the further organizing process takes place on its outer or inner surface. And the nuclei, likewise, may be changed into parts, which contribute to the nutrition of the tissue; but not into its essential elements. These, it must be remarked, are always the product of an ulterior organizing process, connected chiefly with the cell-wall.

There seems reason to believe, that during the organizing process which occurs simultaneously with the changes of the cell, a chemical alteration takes place; for the cells of cartilage sometimes contain fat, and the cartilage of bone prior to ossification contains chondrine, but, after the ossific process, gelatine is found: and it is also stated, that the element which may be obtained from the young cells of areolar tissue is pyine; whereas gelatine is yielded by the fully-formed tissue.

The formation of cells does not cease with the infancy of the organism. These minute organic elements are most important agents in various functions of the body at every period of its existence. By them the secretions are separated; and it is not improbable that they contribute largely to those changes in which nutrition immediately consists. They are found floating in immense numbers in the blood, as well as in the chyle and lymph; and, even in diseased secretions, as pus, they exist in great quantity. In the inflammatory process, they are formed in great abundance; and in the malignant growths, which infest the body, so as to manifest themselves at different parts of it, such as the various forms of cancer, the same organic forms are to be found.

In short, Schleiden and Schwann have proved that the nucleated cell is the agent of most of the organic processes, whether in the plant or animal, from the separation of the embryo from its parent, to the development, growth, and nutrition of the adult individual.

Properties of the Tissues.—The fully-grown tissues manifest differences among themselves, not merely by their anatomical characters, but by their properties. These may be conveniently subdivided into *physical* and *vital*. Strictly speaking, this is a distinction without a difference, for doubtless all the properties of animal tissues may be ascribed to the peculiar arrangement of their particles, and are, therefore, physical. Our reasons for adopting the division will appear in explaining the nature of these properties.

The *physical* properties of the tissues are those which are dependent simply on the peculiar arrangement or mode of cohesion of their constituent particles, as well as upon their chemical constitution, and will

manifest themselves in the dead, as distinctly as in the living, texture. The elasticity of yellow ligament, for instance, is as evident in a specimen which has been preserved in spirits for years, as in one taken fresh from the body. The *vital* properties are those which exist only during life, and which cease immediately when molecular life has ceased. A muscle will contract only so long as it is alive; when dead, it refuses to respond to those stimuli, which so easily excited it while living.

The most striking physical property which certain tissues manifest, is that of *elasticity*, in virtue of which the tissue reacts, after a stretching or a compressing force has been withdrawn. The yellow ligament, which constitutes the ligamenta subflava of the vertebral laminæ, is as elastic as India-rubber; the middle coat of arteries manifests quite as much elasticity. Cartilage is flexible and elastic; and is extensively employed, in consequence of this property, to encrust the articular extremities of the bones, for their protection in the movements of the joints.

The existence of elasticity implies that of *extensibility*. All elastic tissues must admit of being stretched before they can manifest their elastic reaction. But some textures are extensible without being elastic. Such tissues yield only to a long-continued extending force; and, in the healthy state, they are capable of resisting such a force of tension for a considerable period. The resistance which a fibrous membrane offers to the enlargement of an organ or tumour, which it covers, illustrates this statement: the pain felt in hernia humoralis or inflammatory enlargement of the testicle, is doubtless due to the resistance of its fibrous coat to the swelling of the soft substance of the gland.

The various animal tissues exhibit a property of *porosity*, or evince a power of attraction for aqueous fluids. If a piece of areolar tissue from the axilla be soaked in water, it will imbibe it as freely as a sponge. Serous membranes, being chiefly composed of areolar tissue, have the same property, but to a less degree; and the coats of blood-vessels, and hollow membranous viscera, are also porous. The occurrence of transudations, through living and dead tissues, is explained by this property. When the blood is loaded with water, or its passage through the blood-vessels is impeded, or when the vital changes in the blood-vessels go on feebly and imperfectly, their walls exert a morbid attraction upon the water of the contained blood, which transudes into the surrounding areolar tissue, and gives rise to that dropsical effusion, which is commonly called Anasarca. In the minute capillary vessels, this property is always present in a state of health, and the nutrition of the surrounding tissues is effected by the exercise of it. After death, the influence of porosity is favoured by the total absence of motion in the fluids, and of vital change in the walls of the vessels; and, therefore, in the dead body we find the areolar tissue more or less loaded with water in all those places in which gravitation favoured its accumulation. The progress of decomposition, by disintegrating the tissues, also favours the occurrence of transudation.

It is probable that certain vital processes consist solely in transuda-

ion. In this way the watery part of the secretions doubtless escapes rom the blood-vessels, into the canals of the secreting organs; and his is especially likely as regards the mechanism of the kidney, where the blood-vessels of the Malpighian bodies, reduced to their ninutest size, naked, and unassociated with any other tissue, are most avourably placed for the occurrence of this phenomenon; and the bsorption of fluids brought in contact with certain surfaces is explicable on the same principle.

The process, which was first described by Dutrochet, under the name Endosmose and Exosmose, is intimately connected with the orosity of animal tissues. It is a process, "in which the mutual ttraction of two liquids is called into action, one of which is more apable than the other of freely wetting a porous solid which forms art of the combination." (*Daniell's Chemistry.*)

If an animal bladder, the cæcum of a fowl, partially filled with yrup, and tied tightly at its open end with a string, be suspended in vessel of water, it will soon be found distended almost to bursting, n consequence of a considerable quantity of the water having passed hrough the walls into the cavity of the bladder (*Endosmose*). If the xterior fluid be examined, a portion of the syrup will be found to ave passed out of the bladder (*Exosmose*). Or the phenomenon may e illustrated by the following experiment:—Take a funnel, and tie ver its broad end (of three or four inches diameter) a piece of bladder, invert it, and fill it with spirits of wine, and fit to its small end a lass tube, three or four feet in length, and then place it in a vessel f water. In a short time the water will be observed to rise in the ube, and it will ultimately reach the top and flow over. "The first moving power here," says Professor Daniell, "is the force of adhesion between the water and the bladder; the former penetrates the ores of the latter, and comes in contact, upon its upper surface, with he spirit, by the attraction of which, it is removed from the bladder nd mixes with its mass. The height of the column is in some legree the measure of the force thus called into action." The purely hysical nature of this process is shown by the fact that it will equally ake place through porous inorganic substances, as through organic nembranes. It would be impossible to do more here than give a rief explanation of this remarkable phenomenon. It is important o add, that the observations of Dutrochet clearly show that the ature of the septum exerts an important influence upon the direction f the predominant current. If the attraction of the septum for the xterior fluid be the greater, the endosmotic current will prevail, and *vice versâ.*

Endosmose is a more important agent in the vital phenomena of lants than in those of animals. It is supposed, by some physiologists, to be brought into play in the processes of secretion and bsorption.

The animal membranes exercise the property of porosity in reference to gases, as well as to liquids; and the tendency of dissimilar gases to become diffused among each other manifests itself even through compound textures. As in the case of liquids, there is a

double current, when two dissimilar gases are separated by a porous septum, and the predominant current is that which has the strongest attraction for the septum. The following experiments illustrate this phenomenon:—Confine some common air in a jar, by tying tightly over it a piece of sheet-caoutchouc, and then place the jar under a large bell-glass filled with hydrogen gas; the hydrogen will gradually penetrate the partition, distend the caoutchouc, and ultimately burst it. Or, suspend a membranous bag, the stomach of a rabbit, filled with common air, in an atmosphere of carbonic acid; the latter will penetrate to the former and burst the bag. In both instances there is an exosmose greatly inferior in the quantity of gas to the endosmose. In respiration, this phenomenon occurs at every inspiration through the walls of the pulmonary air-cells and the plexus of capillary vessels distributed upon them. (*Daniell's Chemistry.*)

Although in the manifestation of these phenomena there is no direct exercise of vital force, the tissues are not the less dependent on healthy vital action for the preservation of their peculiar properties in a state of integrity. Whoever will compare the compact figure of a vigorous healthy man, accustomed to field-sports and active exercises, with the relaxed, feeble, half-dislocated limbs of an ill-nourished, hysterical woman, will readily perceive how great an influence healthy nutrition must exert in preserving and improving the physical properties of the tissues.

The *vital properties* manifest themselves by a change which occurs in the molecules of certain tissues, as the result of a stimulus applied. The change, thus produced, may be evident from a visible alteration in the tissue stimulated; or it may show itself through a secondary influence exerted upon some other texture or organ, with which the stimulated tissue may be in connection.

These properties exist in two tissues, namely, in muscle and in nerve. A muscle, when stimulated, shortens itself; and, therefore, it is said to possess the property of *contractility*. This power of contracting, in obedience to a stimulus, is characteristic of muscle, and probably occurs in no other kind of animal texture. The stimulus may be direct irritation by mechanical means, or by galvanism, or by some chemical substance; but the natural one, during life, is propagated by the nerves.

In nerve, the vital changes are unaccompanied by any alteration in the tissue itself, which is appreciable by our senses. The excitation or irritation of the nerve may be manifested in three ways: first, by its inducing the contraction of the muscle which it supplies; secondly, by its exciting contraction, in muscles which it does not supply, through a change wrought in the nervous centre; thirdly, by its exciting a sensation. The same stimuli, which we have mentioned as capable of exciting muscular contraction, will produce these effects in nerves; and the will, and other emotions of the mind, are capable of stimulating nerves which are connected with the brain, and exciting action in the muscles to which they are distributed.

That a nerve, when irritated, may excite a sensation, it is necessary that it shall be in connection with the brain. The bodily feelings

of pain or pleasure are thus produced, through the medium of what are called *sensitive* nerves, or nerves of *common sensation;* and we say that the sensibility of any tissue is great or small, according as it is supplied with such nerves in more or less quantity. Tendon, in which probably few nerves exist, is a tissue of low sensibility; whilst the skin, which is largely supplied with nerves, is highly sensitive.

Light, sound, and the sapid and odoriferous qualities of bodies, are capable of stimulating certain nerves, and exciting appropriate sensations in the mind. The nerves which respond to such stimuli, are called nerves of *proper* or *special sensation;* and this name seems appropriate, because these nerves, when otherwise stimulated, excite only their peculiar sensations. If the optic nerve be mechanically irritated, a flash of light is produced; as sometimes occurs if the retina be touched by the needle in the operation for cataract. If the auditory nerves be stimulated by a galvanic shock, a sound is produced. Volta, who tried the experiment on his own person, perceived a hissing and pulsatory sound, which he compared to that of a viscid substance boiling: and Ritter relates, that, upon closing the circle when both his ears were included in it, he was sensible of the sound of G treble; if but one ear was in the circuit, and the positive pole applied to it, the sound was lower than G; if the negative pole was applied to the ear, the sound was higher. (*Müller's Physiology*, translated by Baly.) These peculiarities of the nerves of proper sensation are due to the fact, that at their periphery they are so organized as to be admirably adapted for receiving the impressions of their special stimuli, and at their centres they are connected with those parts of the brain which take cognizance of these special agents. Thus the optic nerve is admirably disposed in the eye for the reception of luminous impressions, and the auditory nerve is beautifully adapted to receive the pulsations of sound, whilst each is connected with a different part of the brain; and what are called subjective phenomena of vision or hearing are often the result of local congestions of blood affecting the respective nerves of these senses, and producing mechanical irritation of them.

In the manifestation of the vital properties, under the influence of appropriate stimuli, it cannot be doubted that an organic molecular change is produced in nerve as well as in muscle. This may be considered as a polar state, in which the ultimate particles of the tissue assume a polarized condition, which may be fairly compared to that which friction or other means can produce in various substances, by which they may be rendered mutually attractive or repulsive. In muscle, it becomes at once evident by the powerful attraction which is exerted between its particles, by which the shortening is effected. In nerve, it is shown by the rapidity with which the change excited by the stimulus at one part of the nerve is conveyed throughout its course to the muscle, or to the brain or other nervous centre, with which it may be connected, producing in them the same or an analogous state.

As these phenomena occur in tissues, whose chemical composition is more complex than that of any others in the body, and which are

the seat of continual changes, they are subject to many disturbing causes, and are easily affected by slight modifications in the general state of the system. Many substances quickly exert an influence upon them, as opium, strychnine, and various sedatives, narcotics, or stimulants. Those properties are therefore entirely dependent on the nutrition of their respective tissues; they quickly vary with the state of that function, and when it ceases, in death, they vanish with it.

For information upon the subjects treated of in this chapter we refer to the following sources:—Henle, Algemeine Anatomie; Berzelius, Chimie Organique. Fr. edit., 1833; Prout on Stomach and Urinary Diseases; Liebig's Animal Chemistry, by Gregory; Graham's Chemistry; Daniell's Chemistry; Schwann, Mikroskopische Untersuchungen über die Uebereinstimmung in der Struktur und dem Wachsthum der Thiere und Pflanzen; Dutrochet, article Endosmose, in the Cyclopædia of Anatomy and Physiology.

CHAPTER II.

FUNCTIONS.—ANIMAL MOTIONS.—MOLECULAR MOTION.—ORGANIC MOLECULAR MOTION.—MUSCULAR MOTION.—CILIARY MOTION.—MOTIONS OF SPERMATOZOA.

The subdivision of the functions of the human organism into the animal and the organic, as already stated, may be adopted as the least objectionable basis for their arrangement. Under the former title we include those functions, which are peculiar to and characteristic of the animal part of the living creation, and to which there is nothing similar or analogous in the vegetable kingdom. These are locomotion and innervation. The *organic* functions are present in both kingdoms, with certain modifications. They are digestion, absorption, circulation, respiration, secretion, and generation.

In examining these various processes, we propose to follow the order in which they have been enumerated. We find it convenient to take the locomotive function first, because so large a proportion of the mechanical arrangements, or of the anatomy of the body, is connected with it. The transition from locomotion to innervation is easy and obvious; for the nervous system has a special connection with the locomotive organs, in order that the influence of the will may be conveyed to them. It may be here stated, that in the animal functions the interference of volition is more frequent than in the organic ones; and that, in all, the nervous system exerts a certain control, and may influence to a great degree the performance of the functions, although some of them are essentially independent of it.

Of the minute movements occurring in the interior of the body.—Of these we may distinguish three kinds: 1. Those in which particles are moved passively by forces independent of themselves. 2. Those accompanying the incessant changes of the organic elements of the tissues. 3. Those which occur in certain entire tissues on the appli-

cation of an appropriate stimulus. All these movements may be called molecular on account of the minuteness of the particles concerned in them.

1. The term *molecular motion* was used many years ago by Mr. Robert Brown, to denote a phenomenon which he had witnessed in the particles of various organic and inorganic substances in a state of extremely minute subdivision. When these particles were suspended in water, they exhibited, under the microscope, motions, which consisted in more or less rapid oscillations and rotations of the particles themselves. He found them in the pollen of plants, in many mineral and metallic substances, in various animal matters, reduced to a subtle powder, consisting of particles that ranged in diameter between the $\frac{1}{15000}$ and $\frac{1}{30000}$ of an inch. The movements are clearly not peculiar to living or organic parts, for they occur in inanimate ones: they never occur excepting when the particles are suspended in water, or some liquid; and they are attributable to currents produced in the fluid by evaporation at its surface or edges, for they may be arrested by covering the fluid with oil, or using other means to prevent such evaporation. They are not, therefore, inherent in the particles themselves, which only obey the impulse communicated to them by the currents created in the fluid which holds them in suspension.

Certain particles, naturally very minute, which are met with in the body, exhibit motions when examined under the microscope floating in fluid. These motions are entirely due to the same cause as would excite them in inorganic particles, namely, to currents in the fluid created by its evaporation. The minute granules, or particles of the chyle, have been found to exhibit molecular motion; and it has been ingeniously supposed, that "these motions indicate the first obvious impress of vitality which the new material has received from its association with living matter." But, before this supposition can be admitted, we require evidence to show that these motions are inherent, and do not result from currents. The minute rod-like bodies, which form the outer coat of the retina, or Jacob's membrane, also sometimes exhibit a molecular motion, when separated and examined in water, and there seems no reason to doubt that this is due to the evaporation of the fluid in which they float.

2. *Organic molecular motion.*—Some of the motions, which take place within the living body, may be compared to those described by Mr. Brown, inasmuch as they are generally, if not always, due to an extraneous force acting upon the particles moved; but they differ in this respect, viz., that the producing force is developed by the processes inseparable from life. Such motions are not in general visible, yet some have been seen, which clearly indicate that forces are developed, during life, capable of producing them. The movements of particles within cells afford an example: such motions are either of a uniform rhythmical kind, or they are apparently irregular and oscillating. Those of the former kind are familiarly known in the vegetable kingdom by the Cyclosis which takes place in the oblong cells of Chara; the granules, which may be seen in motion, are quite passive and are carried along by currents within the cell. Motions of the latter kind

have been seen by Schwann among the granules contained in the cells of the germinal membrane of the hen's egg, as if occasioned by an endosmotic current through the wall of the cell. This membrane is the seat of active change, the development and growth of new cells, destined for the evolution of the textures of the embryo; and they derive their nutriment from the yelk, on the surface of which they lie. Here the contained particles are passive, and the motion in them is only the index of the currents which give rise to it. A molecular motion of the same kind may be seen in the very minute granules, which occupy the cells of the membrane of black pigment on the choroid coat of the eye. Whether this go on during life, it is of course impossible to say, but the conditions for its production are undoubtedly present. In the blood may be seen another example of the kind of motion under consideration. The circulation of this fluid may be readily followed in transparent parts; and certain particles, the blood-discs, which float in it in great numbers, exhibit movements which can scarcely be attributed solely to the current of the circulating fluid. It is probable that secondary currents may be established in the blood, or that attractions and repulsions may exist between the particles themselves, or between them and the walls of the blood-vessels giving rise to these motions. According to some observers, the blood-discs undergo actual changes of shape, becoming now swollen, and now flattened; and this might be attributed to the alternate predominance of endosmose or exosmose. But the statement, that they possess an inherent power of contraction of their own, stands greatly in need of confirmation.

Organic molecular motion occurs in nearly all the internal processes. The introduction of new matter from without into the blood; the removal of effète particles by a process of absorption; the transfer of nutrient matter from the blood to supply the place of the particles thus removed; the separation of organic compounds in glands, cannot take place without a movement of molecules in the textures concerned in these processes. We are as much at liberty to infer, that these motions are produced by certain affinities of the particles of the tissues, as that chemical action is the result of affinities between certain forms of matter. These motions of the organic and inorganic elements are incessant during the ceaseless round of organizing and disorganizing actions of which every tissue is the seat, as long as it continues living. The currents alluded to in the preceding paragraph are visible indications of the presence of these organic movements.

3. The molecular movements of nerve and muscle under stimulation have been already mentioned in the preceding chapter. The capacity of exhibiting these movements exists only while the nutritive process continues to be carried on in the respective tissues—it ceases with life. It would appear that the precise chemical constitution, which is essential to its existence, is of so unstable a nature as to be constantly prone to change, and to require incessant renewal; or, it may be, that this capacity is one which is only developed during the active operation of certain chemical forces, as if it depended ne-

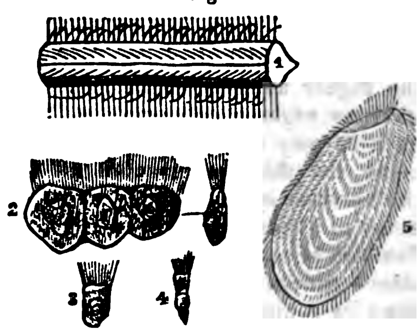
cessarily on certain peculiarities of the organic elements when in a nascent or changing state.

In *muscular movement* there is a visible approximation of the ultimate particles of the tissue in a determinate direction, as will be further explained in the proper place; and in this consists the whole value of muscular tissue as a part of the mechanism of the body. All those motions in the living body which are visible to the naked eye, and many of those which cannot be seen without the aid of lenses, are effected by muscular action. By it canals or tubes adapt themselves to their contents; the heart propels the vital fluid; the digestive canal transmits the ingesta from one part to another; the excretory reservoirs, or ducts, expel their contents; and lastly, by it the attitudes are maintained, and the locomotive function is performed.

Ciliary motion.—In the same category with the molecular motions of the living body we would place that singular phenomenon now well ascertained by multiplied observations, which is called *Ciliary motion.*

Certain surfaces, which are, in their natural and healthy state, lubricated by fluid, are covered with a multitude of hair-like processes, of extreme delicacy of structure and minuteness of size. These are called *cilia*, from *cilium*, an eyelash. They are generally conical in shape, being attached by their bases to the epithelium that covers the surface on which they play, and tapering gradually to a point; or, as Purkinje and Valentin state, they are more or less flattened processes, of which the free extremities are rounded; and this latter form prevails in the human subject. They vary in length from the $\frac{1}{1500}$ to the $\frac{1}{13000}$ of an inch. They are disposed in rows, and are adapted in their arrangement to the shape and extent of the surface to which they belong; they adhere to the edges, or to a portion of the surface, of the particles of the epithelium, preferring the columnar variety of them.

Fig. 2.



Examples of Cilia:—1. Portion of a bar of the gill of the Sea-mussel, *Mytilus edulis*, showing cilia at rest and in motion. 2. Ciliated epithelium particles from the frog's mouth. 3. Ciliated epithelium particle from inner surface of human membrana tympani. 4. Ditto, ditto: from the human bronchial mucous membrana. 5. *Leucophrys patula*, a polygastric infusory animalcule: to show its surface covered with cilia, and the mouth surrounded by them.

During life, and for a certain period after death, these filaments exhibit a remarkable movement, of a fanning or a lashing kind, so that each cilium bends rapidly in one direction, and returns again to the quiescent state. The motion, when viewed under a high magnifying power, is singularly beautiful, presenting an appearance somewhat resembling that of a field of corn agitated by a steady breeze. Any minute objects coming in contact with the free extremities of the cilia are hurried rapidly along in the

direction of the predominant movement; one or more blood-discs, accidentally present, will sometimes pass rapidly across the field, propelled in this way, and very minute particles of powdered charcoal may be conveniently used to exhibit this phenomenon, and to indicate the direction of the movement. The action of the cilia produces a current in the surrounding fluid, the direction of which is shown by the course which the propelled particles take.

An easy way to observe this phenomenon is to detach by scraping with a knife a few scales of epithelium from the back of the throat of a living frog. These, moistened with water, or serum, will continue to exhibit the movement of their adherent cilia for a very considerable time, provided the piece be kept duly moistened. On one occasion we observed a piece prepared in this way exhibit motion for seventeen hours; and it would probably have continued doing so for a longer time, had not the moisture around it evaporated. However, Purkinje and Valentin have observed it to last for a much longer time than this in connection with the body of the animal. In the turtle, after death by decapitation, they found it lasted, in the mouth, nine days; in the trachea and the lungs, thirteen days; and, in the œsophagus, nineteen days. In frogs, from which the brain had been removed, it lasted from four to five days. The longest time they observed it to continue in man and mammalia was two days; but in general it did not last nearly so long. What appears to be immediately necessary to the continuation of the movement, is the integrity of the epithelial cells to which the cilia adhere; for as soon as these shrink up for want of moisture, or become physically altered by chemical reagents or by the progress of putrefaction, the cilia immediately cease to play.

From these facts we learn two important points in connection with this phenomenon. The first is, the truly molecular character of the movement. Whatever be the immediate cause of the action of the cilia, it is evidently intimately connected with the minute epithelial particles to which they are attached; for cilia never exist in man and the higher animals without epithelial particles, and these particles have no organic connection with the subjacent textures, excepting such as may arise from simple adhesion. And, secondly, we perceive, that this movement is independent of both the vascular and the nervous systems, for it will continue to manifest itself for many hours in a single particle isolated from the rest of the system. After death it remains longer than the contractility of muscle; a circumstance which, together with the facts just mentioned, indicates that the cilia cannot be moved by little muscles inserted into their bases, as some have supposed. And experiment also shows this independence. If the abdominal aorta be tied, the muscles of the lower extremities will be paralyzed in consequence of their being deprived of their blood; and on removing the ligature, and allowing the blood to flow, the muscles will recover themselves. But a ciliated surface is not affected at all in its movements, though the supply of blood to the subjacent tissues be completely cut off. Again, hydrocyanic acid, opium, strychnine, belladonna, substances which exert a powerful effect

on the nervous system, produce no influence upon ciliary motion. In the bodies of animals killed by these poisons, the phenomenon is still conspicuous; and even the local application of them does not hinder it, provided the solutions do not injure the epithelial texture. Shocks of electricity passed through the ciliated parts, do not affect the movement. Lastly, the removal of the brain and spinal cord in frogs, by which all muscular movements are destroyed, does not stop the action of the cilia. This striking fact may likewise be adduced to disprove the supposition, that these movements result from the action of minute muscles; for, although muscles may be excited to contract without nerves, we have no instances in the higher animals in which they habitually act without the interference of the nervous system; nor is it likely that a movement existing over so extended a surface, as that by the cilia, would, if effected by muscles, be independent of nervous influence.

Alterations of temperature affect the ciliary motion, owing, doubtless, to the physical change they induce in the epithelial particles. In warm-blooded animals it ceases on a reduction of the temperature below 43°F. In cold-blooded animals, however, it continues even at 32°. In all, a very high temperature effectually puts a stop to it. It is interesting to notice, that all observers agree in stating, that blood is the best preservative of the ciliary motion, but the blood of vertebrata destroys it in the invertebrata. Bile puts a stop to it, very probably by reason of its thick and viscid nature, and not from any chemical influence.

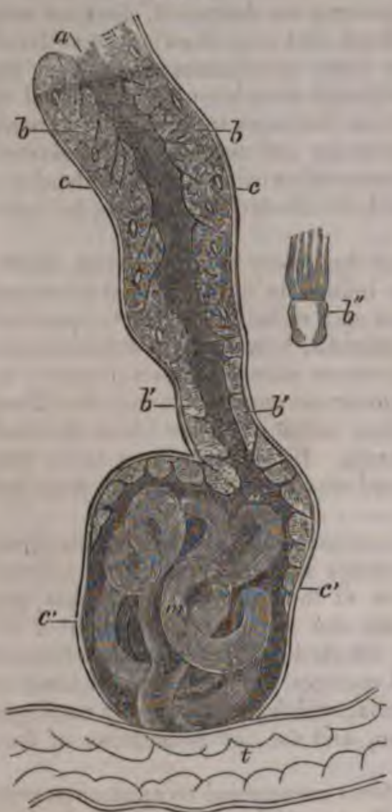
This phenomenon exists most extensively in the animal kingdom. It has been found in all the vertebrate classes; and in the invertebrata likewise, with the exception of the crustacea, arachnida, and insects. It is the agent by which the remarkable rotation of the embryo in the ova of mollusca is effected; and it occurs on the surface of the ova of polypes and sponges. The bodies of some of the infusoria are covered with cilia, which are apparently employed by them as organs of locomotion, and for the prehension of food (5, fig. 2.)

In man, the ciliary motion has been ascertained to exist on several surfaces:—1. On the surface of the ventricles of the brain and on the choroid plexuses. So delicate are the cells of epithelium here, that the slightest mechanical injury destroys them; it is, therefore, very difficult to see the movement. Valentin states that its duration is considerable in these parts, so that it may be seen in subjects used for dissection. 2. On the mucous membrane of the nasal cavities, extending along the roof of the pharynx to its posterior wall, on a level with the atlas, on the upper and posterior part of the soft palate, and, in the immediate neighbourhood of the Eustachian tube, extending through the tube itself to the cavity of the tympanum. 3. On the membrane lining the sinuses of the frontal bone, the sphenoid, and the superior maxillary. 4. On the inner surface of the lachrymal sac and lachrymal canal. 5. On the membrane of the larynx, trachea, and bronchial tubes. 6. On the lining membrane of the female organs of generation. It does not exist in the vagina; but it may be

traced from the lips of the os uteri, through its cavity, and through the Fallopian tubes to their fimbriated margins.

In nearly all these instances there appears to be a mechanical use for the ciliary movement, namely, to promote the expulsion of the fluid secreted by the surfaces on which the cilia exist. Wherever the direction of the motion has been ascertained, it is that which would be favourable to such a purpose. In the bronchial tubes and trachea, the direction of the motion is towards the larynx, so that the cilia may be regarded as agents of expectoration. In the nose of the rabbit, Dr. Sharpey observed the impulse to be directed forwards, and in the maxillary sinus it appeared to pass towards the back part of the cavity, where its opening is situated. In the Fallopian tube, the direction is stated by Purkinje and Valentin to be from the fimbriated extremity towards the vagina. It seems very probable that ciliary motion exists in the kidney, at the narrow neck of each uriniferous tube, as it passes off from the capsule of the Malpighian body. This has not been actually observed in the human subject. It was discovered, and has been frequently seen in the frog, (*Bowman*, *Phil. Trans.*, 1842,) and is shown in the annexed drawing, (fig. 3.) The movement is here directed towards the uriniferous tube, and it doubtless is destined to favour the flow of the aqueous portion of the secretion from the capsule to the tube.

Fig. 3.



Uriniferous tube of Frog's kidney, arising from capsule of Malpighian body:—*a*. Cavity of the tube. *b*. Epithelium. *c*. Basement membrane. *b'*. Ciliated epithelium at the neck of the tube. *b''*. Detached ciliated particle. *c'*. Malpighian capsule. *m*. Malpighian tuft.

In the inferior animals the cilia seem to answer a similar end to that in man. They exist extensively on respiratory surfaces, and in connection with the generative organs; and also, but to a less degree, with the organs of digestion. But in some situations, both in man and in the inferior creatures, it is difficult to determine what functions the ciliary motion can perform. Such are, in man, the ventricles of the brain; and, in the frog, the closed cavities of the

pericardium and peritoneum. Here there are no excretory orifices, toward which the current might set.

What is the cause of ciliary motion? We have shown it to be independent of the blood and of the nerves, and to resist those depressing causes which usually put a stop to the action of contractile tissue. It requires for its continuance three conditions: a perfect epithelium cell; moisture, not of too great density; and a temperature within certain limits. From Schwann's observations it appears that cells exhibit a power of endosmose; that a chemical change occurs in the fluids in contact with them; and that a movement of their internal granules may be seen under certain circumstances. If ciliated epithelium cells exert an attraction of endosmose upon the surrounding fluid, may not this physical phenomenon afford a clue to determine the cause of the movement?

A very remarkable movement is manifested by certain particles found in the secretion of the testicle, which prevails most extensively throughout the animal series, and is even found among plants. From the regularity of these movements and their resemblance to those of minute animals, a place had been assigned by naturalists to the particles in question, in their zoological classifications, under the name "*Cercariæ seminis*," Spermatozoa, or Spermatic animalcules, and Ehrenberg refers them to the Haustellate Entozoa. These particles consist chiefly of a long filament or tail, which is sometimes swollen at one extremity, to form the body of the supposed animalcule. The motions consist in a sculling action of the tail, or a slight lateral vibration of it. In many of its conditions it closely resembles ciliary motion; and its duration after death, or after the separation of the fluid, is pretty much the same as that of the ciliary movements. The particles are extremely minute, even measured in their length; but especially so in thickness. They are, therefore, well adapted to obey those impulses which we have shown to be capable of giving rise to molecular motions. We shall return to this curious subject again in discussing the function of generation.

On the subjects treated of in this chapter reference is made to the following sources of information:—Rob. Brown, A brief Account of Microscopical Observations on the particles contained in the pollen of plants, and on the general existence of active molecules in organic and inorganic substances; Purkinje and Valentin, Commentatio Physiologica de phenomeno motûs vibratorii continui; article Cilia, by Dr. Sharpey, in the Cyclopædia of Anatomy and Physiology; Valentin's article Flimmer-bewegung in Wagner's Handworterbuch der Physiologie.

silk. But, on more accurate inspection, it is found impossible to distinguish threads of a determinate size; they seem, indeed, to be of various sizes, according to the degree of splitting to which the whole has been submitted, and many are to be seen so very minute as at first almost to elude the eye. In other parts the mass splits up into membranous rather than filiform fragments; so that it would appear incorrect to describe this tissue as a bundle of threads. It is rather a mass, with longitudinal parallel streaks, (many of which are creasings,) and which has a tendency to slit up almost *ad infinitum* in the longitudinal direction. The correctness of this view is further shown by the action of acid, which obliterates, for the most part, all appearance of fibrillæ, and swells it up as an entire mass.

Physical and vital properties.—White fibrous tissue is *inelastic*, and, under ordinary circumstances, *inextensible;* though it does admit of being somewhat stretched by the influence of a long-continued and slowly acting force, as is seen occasionally when an effusion of fluid has taken place into an articular cavity, or when a tumour has slowly grown under a fascia. Its force of cohesion is the most valuable and characteristic quality of the white fibrous tissue, and to this its various important uses are chiefly due. Mascagni calculates the force requisite to rupture the tendo-Achillis as equal to 1,000 pounds' weight. Instances are constantly seen where muscles are torn, or bones fractured, while the tendons or ligaments, through which the force has acted, have escaped. Thus, the malleoli are often dragged off by twists of the foot acting on those processes of bone through the lateral ligaments of the joint. It is entirely devoid of contractility or irritability; and its sensibility is very low, so much so that tendons hanging out of a wound have been cut without the patient being aware of it.

Vessels and Nerves.—White fibrous tissue contains few vessels; they are small, and follow for the most part the course of the bundles of the tissue; they appear more numerous in the dura mater, and in periosteum, than in other parts. The presence of nerves, and their mode of subdivision, have not as yet been satisfactorily demonstrated anatomically; we infer their existence from the tissue manifesting sensibility in some forms of disease.

Chemical composition.—The flexibility of fibrous tissue is owing to its containing a small proportion of water. A tendon, ligament or fibrous membrane, will dry readily; it then becomes hard and rigid; it resists the putrefactive process when not kept moist, and even then putrefies less readily than the softer textures. Acetic acid causes it to swell up, instantly removes its peculiar appearance of wavy fibres, and displays some broken elongated corpuscles, which are probably the remains of the nuclei of the development-cells. Gelatine may be extracted in considerable quantity from white fibrous tissue by boiling, and it would appear to constitute its chief proximate principle.

Of the different forms of white fibrous tissue.—A. *Ligaments.*—Ligaments are connected with joints. They pass in determinate directions from one bone to another, and serve to limit certain move-

ments of the joint, while they permit others. They, therefore, constitute an extremely important part of the articular mechanism in preserving the integrity of the joint in its various movements. There are three principal kinds of articular ligaments:—1. *Funicular*, rounded cords of white fibrous tissue, of which we may give as examples the external lateral ligament of the knee-joint, the perpendicular ligament of the ankle-joint, &c.: 2. *Fascicular*, flattened bands, more or less expanded; ex. internal lateral ligament of the knee-joint, lateral ligaments of the elbow-joint, anterior and posterior ligaments of the wrist-joint, and, indeed, the great majority of ligaments in the body: 3. *Capsular;* these are barrel-shaped expansions, attached by their extremities around the margin of the articular surfaces composing the joint, and forming a complete but a loose investment to it, so that its movements are not particularly restricted in one direction more than another. They constitute one of the anatomical characters of an enarthrodial or ball-and-socket joint, and are found in the only two perfect examples of that form of articulation, namely, the shoulder and hip joints.

B. *Tendons.*—Tendons serve to attach muscle to bone, or some other part of the sclerous system. We may enumerate three varieties of tendon, as regards form: 1. *Funicular, e. g.*, long tendon of the biceps cubiti; 2. *Fascicular*, short tendon of the same muscle, and most of the tendons of the body; 3. *Aponeurotic*, tendinous expansions, sometimes of considerable extent, and very useful in protecting the walls of cavities. The tendons of the abdominal muscles afford good examples of this variety.

The tendons are for the most part implanted by separate fascicles into distinct depressions in the bones, and are also closely incorporated with the periosteum; so that in maceration, when the latter is separated, it becomes easy to remove the tendons. In some birds, whose tendons are black, the periosteum is black also; and in the human subject we may often see the tendinous fibres continued on the surface of the periosteum, as a shining silvery layer, following the primitive direction of the tendinous fibres, from which they were derived; a marked example of this may be seen on the sternum, in front of which the tendinous fibres of the opposite pectoral muscles meet and decussate, and thus form the superficial layer of the periosteum covering that bone. The length of the tendons is beautifully adapted to the quantity of contractile fibre required to perform a certain movement; thus, in the biceps cubiti, were the whole length between the scapula and radius occupied by muscular fibre, there would be a great waste of that contractile tissue, as there would be much more than is wanted to produce the required motion; tendon is, therefore, made to take the place of the superfluous muscle: in this way we may explain the differences in length of the tendons even in the same limb.

C. *Membranous.*—In the form of an expanded membrane white fibrous tissue is used to cover, protect, and support various parts. Under such circumstances we often find that it not only forms an external covering to them, but that it sends in processes or septa, which

separate certain subdivisions or smaller parts. Thus, the fascia lata of the thigh not only invests the muscles of the thigh, but sends in processes which pass down to the periosteum, and separate the several muscles from each other; and the dura mater of the cranium sends in processes by which certain portions of the encephalon are separated from one another.

Reparation and Reproduction.—When a solution of continuity takes place in white fibrous tissue, it readily heals by the interposition of a new substance, every way similar to the original tissue, excepting that it wants its peculiar glistening aspect, and is more bulky and transparent.*

2. *Yellow Fibrous Tissue.*—In colour, and in the possession of elasticity to a remarkable extent, this tissue differs manifestly from that last described.

It is yellow: disposed in bundles of fibres, and covered by a thin sheath of areolar tissue, which likewise sinks in among its fibres. In man it exists in the fascicular, funicular, and membranous forms.

Fig. 5.

1

Yellow fibrous tissue, showing the curly and branched disposition of its fibrillæ, their definite outline, and abrupt mode of fracture. At 1, the structure is not disturbed, as in the rest of the specimen.—Magnified 320 diameters.

Under the microscope we observe it to consist of fibres, round in some, flattened in other specimens. These fibres are very variable in diameter, usually from $\frac{1}{5000}$ to $\frac{1}{10000}$ of an inch in diameter. They bifurcate, or even divide into three; and the sum of the diameters of the branches considerably exceeds the diameter of the trunk. They anastomose freely with each other. They are prone to break under manipulation, and the broken extremities are abrupt and disposed to curl up: when many of these broken ends exist together in the same piece, they give it a very peculiar and characteristic appearance.

In the human subject we find this tissue employed in the spine, as the *ligamenta subflava*, extended between the laminæ of the vertebræ; in the larynx, forming the thyro-hyoid and crico-thyroid membranes, and the chordæ vocales; and in the trachea, forming the longitudinal or elastic bands of that tube, and of its branches. The internal lateral ligament of the lower jaw, the stylo-hyoid ligament, and the transversalis fascia of the abdomen, are also, in a great measure, composed of it. Among the lower animals it is very extensively used for mechanical purposes, of which there is a familiar instance in the *ligamentum nuchæ* of quadrupeds. Its great elasticity fits it for restoring parts after they have been moved by muscular action. Hence it is generally employed to supply an antagonist force to the muscular.

A peculiar modification of the yellow fibrous tissue composes the proper coat of the arteries, and it will be described with the blood-vessels.

* We have ascertained this in the case of a divided tendo-Achillis.

In *chemical constitution*, this tissue differs remarkably from the white fibrous tissue. It is unaffected by the weaker acids, or by boiling, and will resist putrefaction, and preserve its elasticity during a very long period. Very long boiling appears to extract from it a minute quantity of a substance allied to gelatine; but this is perhaps derived from the areolar tissue and vessels, which always penetrate sparingly among its fibres, and cannot be separated by dissection.

There appear to be no vestiges of the nuclei of cells in this tissue; at least we have failed to detect them.

We have hitherto spoken of the two forms of fibrous tissue as they occur in isolated masses; but their distribution through the body is far more extensive than this description would imply. In a diffused form, blended with one another in very varying proportions, and each one of them presenting a variety of modifications, they compose the *areolar tissue*, which may now be conveniently considered under a separate head.

OF THE AREOLAR TISSUE.

(Cellular or Filamentous Tissue.)

This is very widely dispersed among the other tissues of the body, and of itself constitutes a principal portion of some organs. It serves the most important purposes in the *construction* of the body, by binding together, and yet allowing movement between, its elementary parts: and it contributes largely to the formation of membranes conferring protection by their toughness, resistance, and elasticity.

Microscopic characters.—When a fragment of the areolar tissue from a favourable situation is examined, it presents an inextricable interlacement of tortuous and wavy threads intersecting one another in every possible direction. They are of two kinds. The first are chiefly in the form of bands of very unequal thickness, and inelastic. Numerous streaks are visible in them, not usually parallel with the border, though taking a general longitudinal direction. These streaks, like the bands themselves, have a wavy character, but they are rendered straight by being stretched. The streaks seem more the marks of a longitudinal creasing, than a true separation into threads: for it is impossible by any art to tear up the band into filaments of a determinate size, although it manifests a decided tendency to tear lengthwise. The larger of these bands are often as wide as $\frac{1}{500}$ of an inch; they branch, or unite with others, here and there. The smaller ones are often too minute to be visible, except with a good instrument. These are the *white fibrous element*.

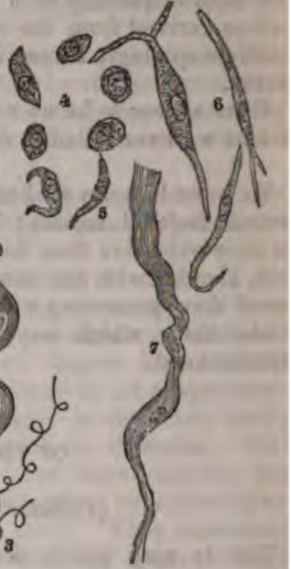
The others are long, single, elastic, branched filaments, with a dark, decided border, and disposed to curl when not put on the stretch. These interlace with the others, but appear to have no continuity of

substance with them. They are for the most part about the $\frac{1}{8000}$ of an inch in thickness; but we often see, in the same specimen, others

Fig. 6.

The two elements of Areolar tissue, in their natural relations to one another:—1. The white fibrous element, with cell-nuclei, 9, sparingly visible in it. 2. The yellow fibrous element, showing the branching or anastomosing character of its fibrillæ. 3. Fibrillæ of the yellow element, far finer than the rest, but having a similar curly character. 8. Nucleolated cell-nuclei, often seen apparently loose.—From the areolar tissue under the pectoral muscle, magnified 320 diameters.

Fig. 7.



Development of the Areolar tiss (white fibrous element):—4. Nucl ated cells, of a rounded form. 5, 6. The same, elongated in different d grees, and branching. At 7, th elongated extremities have join others, and are already assuming distinctly fibrous character.—Aft Schwann.

of much greater density. These form the *yellow fibrous elemen* (fig. 6.)

These two tissues may be most easily discriminated by the additio of a drop of dilute acetic acid, which at once swells up the forme and renders it transparent, while it produces no change in the latte The wavy bands of the white fibrous part, on being touched by th acid, may be seen to expand *en masse*, and not as though they con sisted of a mere bundle of smaller filaments; yet there often remain in them an appearance of more or less wavy transverse lines at prett equal distances, remotely resembling those on the fibre of striped mus cle. These we are unable to explain. The acid also brings int view *corpuscles* of an oval shape, often broken into fragments, an stretching for some distance along the interior of the band. Thes seem to be the nuclei of the cells from which the bands have bee originally produced.

In the earliest period at which the areolar tissue can be examined Schwann has described it as consisting of nucleated particles, sendin

offsets on the opposite sides, and connecting themselves with others in the vicinity. The threads thus formed are at first homogeneous; the longitudinal streaks and the wavy character appear subsequently (fig. 7). His description is drawn from the white fibrous element; but it may be extended to the yellow also.

We have observed frequently among the threads of areolar tissue taken from adult subjects a number of corpuscles (8, fig. 6), either isolated, or having very delicate prolongations among the neighbouring threads. These seem with great probability to be either advancing or receding stages of the tissue.

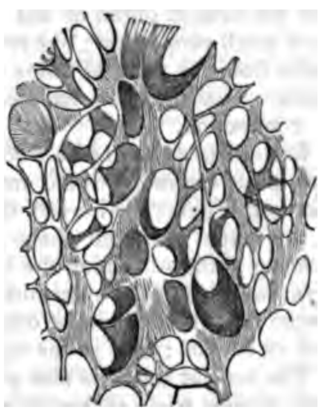
It is not known whether the ultimate elements of the areolar tissue have any immediate attachment or union with the other tissues, among which they lie, or whether they merely enclose them by the complexity of their web.

By the endless crossing and twining of these microscopic filaments, and of fasciculi of them, among one another, a web of amazing intricacy results, of which the interstices are most irregular in size and shape, and all necessarily communicate with one another.

This is well seen by forcibly filling the tissue with air or water in any region. In the living body this is very obvious in anasarca, and in traumatic emphysema, as in the remarkable case related by Dr. W. Hunter in his celebrated paper (*Med. Obs. and Inquir.*, vol. ii. p. 17), where the whole body was blown up so tensely as to resemble a drum.

The interstices are not cavities possessed of definite limits, because they are open on all sides, and ultimately constituted out of a mass of tangled threads. The application of the term, *cell*, to them, is therefore inappropriate; and it cannot be wondered at, that it should have led to much confusion. In certain situations, however, where this tissue is in great abundance, and where it first attracted attention at the time when elementary tissues began to be separately studied, the meshes thus formed are disposed so as to constitute secondary cavities, having a somewhat determinate shape and size, and which are visible to the naked eye. These generally contain fat, and may be admirably studied in most parts of the subcutaneous tissue. They are better deserving the name of cells than the interstices formed by the first interlacement of the elementary filaments. But they communicate freely, as the smaller interstices do, their walls being everywhere cribriform, and capable of giving passage to air or fluids.

Fig. 8.



Portion of Areolar tissue, inflated and dried, showing the general character of its larger meshes. Each lamina and filament here represented contains numerous smaller ones matted together by the mode of preparation.—Magnified twenty diameters.

The areolar tissue is one of the most extensively diffused of all the elements of organization, and its chief purpose seems to be that of connecting together other tissues in such a way as to permit a greater or less freedom of motion between them. To do this, it is placed in their interstices, and is more or less lax, more or less abundant, according to the particular exigency of the part. It is by means of this tissue, as well as by the complexity of its own web, that almost every part of the vascular system is fixed in its position, and allowed to undergo the movements impressed upon it by the circulative powers. Even the capillaries supplying this system itself are for the most part brought to it, and enveloped, by this tissue.

So true and comprehensive is this description of the association of the areolar tissue with the vascular, that it would be difficult to point out a single instance in which one office of the former is not to envelop and protect the latter. But the statements that have been made of its universal presence have no good evidence in their favour. In the compacter parts of bone, in teeth, and in cartilage, it is certainly not present; and, indeed, it could serve no purpose in those structures. In the substance of the brain, also, it does not exist, excepting around the vessels two or three removes from the capillaries.

In the muscles it connects the elementary fibres to one another, and preserves them from undue separation during contraction; but even here it is bound within the same limits as the capillaries, not penetrating the sarcolemma to touch the contractile element within. It enters the muscles abundantly along with their vessels and nerves. It is remarkable, however, that the central organ of the circulation, like the central organ of the nervous system, contains this tissue in very small proportion; one reason of which seems to be, that its fibres differ from the parallel fibres of other muscles, by twining among one another, and thus are enabled to dispense with an extraneous bond of connection.

Besides penetrating between the fibres of the muscles, whose minute parts are in continual movement upon one another during contraction, it generally invests their exterior, in a profusion proportioned to the extent to which these organs move as a whole upon neighbouring parts, of which the best examples may be seen between the great muscles of the extremities; between these and their enveloping fasciæ (not their fasciæ of origin); under the occipito-frontalis muscle and its tendon; and in the upper eyelids.

The areolar tissue is also present in immense quantities under the skin of most parts of the body, and especially where great mobility of the integument is required, either as a protection to deeper organs against external violence, or to facilitate the various movements of the frame. Such are the regions of the abdomen, and of several of the articulations, and the eyelids.

Around internal organs which change their form, size, or position in the routine of their functions, and which are wholly or partially without a free surface, as the pharynx, œsophagus, lumbar colon, bladder, &c., this tissue is abundant, and its filaments so long, tortuous,

and laxly interwoven, as to admit of a ready and extensive motion on the neighbouring viscera.

This tissue likewise forms a layer lying under the mucous and the serous membranes in almost every situation, though presenting great variations of quantity and denseness: it renders the movements of such parts easy. It also closely invests the exterior of every gland and parenchymatous organ, and enters more or less abundantly into its inner recesses, along with its vessels, nerves, and absorbents: but there is no doubt that it has been supposed to have a much greater share in the formation of this numerous class of organs than an ultimate anatomical analysis of them, conducted with careful precision, will at all warrant. In all these cases it is a more or less copious attendant on the vessels; but wherever, either from the intricacy of the interlacement of the capillaries with the other *essential* elements of the particular organ, or the greater strength of these elements themselves, the firm contexture of the whole is provided for, while little or no motion is required between its parts, this interstitial filamentary tissue will be found to be confined to the larger blood-vessels, and to the *surface* of the natural subdivisions of the organ.

For the present, it may be sufficient to illustrate this remark by contrasting two important glands, in reference to this point. The *liver* is well screened from injury by its position; it is liable to no change of bulk; it consists throughout of a continuous and close network of capillaries, the interstices of which are filled by the nucleated secretion-particles. The lobules resulting from the distribution of the vessels and ducts blend together at numerous points, and have no motion on one another. Here the areolar tissue is in very small quantity, and is limited to the ramifications of the vessels and ducts. The *mamma*, on the other hand, is, by its situation, peculiarly obnoxious to external injury. It is broken up into numerous subdivisions, which move with the utmost freedom on one another, and it is moreover liable to temporary augmentations of bulk. In this important gland not only is there a common investment of peculiar density, but an extraordinary abundance of areolar tissue disseminated throughout its interior.

Thus, this tissue, so widely spread throughout the body, whether it serve the purpose of an investment to large segments or masses, under the form of a membrane, strengthening and protecting them, and escorting their vessels and other components into and from their substance (atmospheric), or as a web of union between the simplest elements of their organization (parenchymal), is to be regarded as rather taking a subordinate or ministering share in the constitution of the frame, than as being of primary importance in itself.

It is a cement that allows of separation between what it binds together; and it accomplishes this double purpose in a manner suited to the necessities of diverse parts, by a variety so simple in the number, intricacy, and closeness of its threads, as to be worthy of the highest admiration, while it is wholly inimitable by art.

Where great elasticity is required, the yellow element preponde-

rates; while the white fibrous element abounds in parts demanding tenacity and power of resistance. In all cases the openness of the network is proportioned to the extent of mobility required. Where the meshes are small, the threads composing them branch and anastomose with one another with much greater frequency. The texture of the cutis affords the most characteristic example of this condition.

Physical properties.—These have only been studied hitherto in those situations where the tissue exists in great abundance, as in the subcutaneous fascia, the sheaths of muscles, &c. It has here a whitish hue, especially when steeped in water. It is extensible in all directions, and is very elastic, returning to its original disposition after stretching. It possesses no contractility beyond that attributable to the vessels which are everywhere found in connection with it, and in such situations in great profusion. Its sensibility is usually stated to be low; but it may be doubted whether the nerves can in any case be said to be distributed to this tissue, which has been already shown to be an appendage and protector to these and other organs. Its asserted powers of absorption and secretion appertain to the capillary blood-vessels, rather than to the threads of the areolar tissue.

This tissue, like all other soft solids, contains a large quantity of water. This keeps the filaments moist, without being so abundant as to be free in their interstices. A morbid increase of this fluid in the subcutaneous areolar tissue occasions the condition called anasarca, and which may be known by the skin pitting under the pressure of the finger.

When dried, out of the body, areolar tissue becomes hard and transparent, but resumes its former state if moistened. It undergoes the putrefactive process slowly. It is one of that class of tissues which yields gelatine by boiling, the gelatine being derived from the white fibrous element only.

The great value of areolar tissue, in facilitating the motion of parts between which it is situate, is shown by the effects of inflammation, or other diseases which injure its physical properties. It is well known, that, when the subcutaneous tissue is the seat of phlegmonous inflammation, the movements of the part affected are stiff and painful, or altogether impeded, because the subjacent muscles cannot move freely, by reason of the loss of elasticity in the areolar tissue. When this tissue becomes indurated by an effusion of coagulable material, the movements of the diseased limb are similarly impaired.

OF THE ADIPOSE TISSUE, AND OF FAT.

This tissue has no alliance either of structure or function with the areolar tissue; it is, however, usually deposited in connection with that tissue, and therefore we find it convenient to notice it here. Malpighi, W. Hunter, Monro, and, more recently, other distinguished

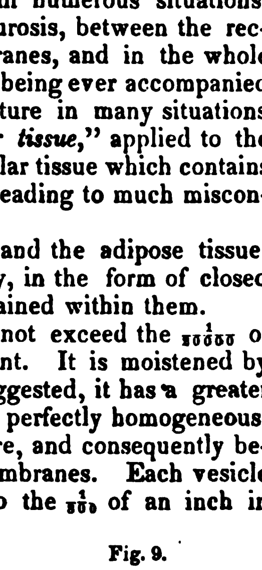
anatomists, pointed out the distinctness of these two tissues; but such has been the influence of the term *cellular*, applied to both, that they are still usually classed together. Now, however, that microscopes, on which reliance can be placed, declare their totally distinct nature, it is full time that they be treated of as altogether distinct and independent tissues.

A common use of the adipose tissue being to occupy spaces of various dimensions left in the interstices between organs, and thus to facilitate motion and contribute to symmetry, it is very commonly closely associated with the areolar tissue; but the connection is not an essential one. In the cancelli of bones there is a large deposit of fat, but none of this filamentary tissue; and in numerous situations, as the eyelids, beneath the epicranial aponeurosis, between the rectum and bladder, under the mucous membranes, and in the whole of the cutis, the areolar tissue exists without being ever accompanied by fat. Nevertheless, their apparent admixture in many situations has given rise to the term "*adipose cellular tissue*," applied to the two combined, as distinguished from that areolar tissue which contains no fat. This term should be discarded as leading to much misconception.

A distinction is to be drawn between fat and the adipose tissue. The *tissue* is a membrane of extreme tenuity, in the form of closed cells or vesicles; the *fat* is the material contained within them.

The *membrane of the adipose vesicle* does not exceed the $\frac{1}{10000}$ of an inch in thickness, and is quite transparent. It is moistened by watery fluid, for which, as Mr. Paget has suggested, it has a greater attraction than for the fat it contains. It is perfectly homogeneous, having no appearance of compound structure, and consequently belongs to the class of simple or elementary membranes. Each vesicle is a perfect organ in itself; is from the $\frac{1}{300}$ to the $\frac{1}{800}$ of an inch in diameter, when fully developed; and is supplied on its exterior with capillary blood-vessels, having a special disposition.

Fig. 9.

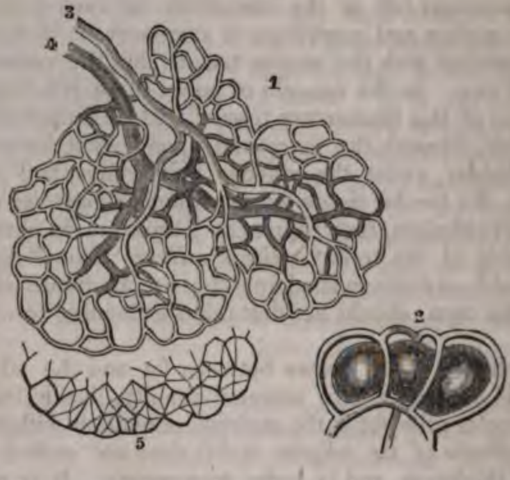


Fat vesicles, assuming the polyhedral form from pressure against one another. The capillary vessels are not represented.—From the omentum: magnified about 300 diameters.

The fat vesicles are usually deposited in great numbers together, and they then become flattened on their contiguous aspects, and assume a polyhedral figure more or less regular (fig. 9). But, if isolated, their form is rounded, as may be seen in eminent beauty in the double series of them which frequently accompanies the minute vessels traversing membranous expansions of the areolar tissue, and other lamellar structures, as the mesentery of small animals. The vessels are thus attended by fat vesicles, for the manifest purpose of protection from the pressure to which they would be exposed in their open course, and they throw around each vesicle a capillary loop.

Where the fat is in considerable quantity, it is commonly subdivided into a number of small fragments or lobules, fitted accurately to one another and invested with areolar tissue, for the purpose, chiefly, of permitting motion between the parts of the mass, but, also, for the convenience of the distribution of its blood-vessels.

Fig. 10.



Blood-vessels of Fat:—1. Minute flattened fat-lobule, in which the vessels only are represented. 3. The terminal artery. 4. The primitive vein. 5. The fat vesicles of one border of the lobule, separately represented. Magnified 100 diameters.—2. *Plan* of the arrangement of the capillaries on the exterior of the vesicles: more highly magnified.

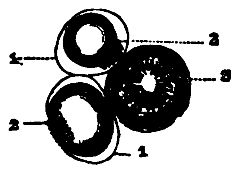
The blood-vessels enter the chinks between the lobules (fig. 10, 1, 2), and soon distribute themselves through their interior, under the form of a solid capillary network, whose vessels occupy the angles formed by the contiguous sides of the vesicles, and anastomose with one another at the points where these angles meet. This is one of those situations where the capillary vessels can be most unequivocally proved to possess distinct membranous parietes.

Fat.—Fat is a white or yellow unctuous substance, unorganized, and secreted into the interior of the adipose vesicles. Chemists have distinguished in it two solid proximate principles, *stearine* and *margarine*, combined with a fluid one, or oil, *elaine;* on the relative proportions of which the principal of the numerous modifications of its external qualities would seem to depend. These principles may be obtained by different means. Boiling alcohol dissolves both, but on cooling deposits the stearine in snow-white flakes; and the elaine may be set free by the addition of water, for which the alcohol has a superior affinity. Or, the elaine may be separated by pressure. Stearine preserves its solidity at a temperature of 167° Fahr., and elaine remains fluid at 63° or 65° F. Margarine exists along with stearine in most fats, and may be separated from it by ether, which dissolves margarine, but not stearine; it is said to exist alone in human fat, which is therefore destitute of stearine. These proximate

elements of fat are regarded by modern chemists as natural compounds of certain organic acids with an organic base, to which the name of *glycerine* has been given, from its sweet taste. The acids are, the *stearic*, *margaric*, and *elaic*; and the proximate principles are, respectively, a stearate, a margarate, and an elaate of glycerine. By boiling oil or fat with a solution of caustic alkali, the acids unite with the potash, forming soap, and the glycerine remains dissolved in the liquid. By evaporating this liquid (in which any excess of alkali had been previously neutralized by tartaric acid) to a thick syrup, the glycerine may be obtained from it in solution by strong alcohol.

We may often detect a spontaneous separation of these two proximate principles within the fat vesicle of the human subject. The solid portion collects in a spot on the inner surface of the cell-membrane, and looks like a small star (fig. 11, 2, 2, 2). The elaine occupies the remainder of the vesicle, except when the quantity of fat in the cell is smaller than usual; in which case we may often discern a little aqueous fluid between the elaine and the cell-membrane on the side farthest from the star (fig. 11, 1, 1,): a condition, by the way, which is very favourable for the observation of this membrane itself.

Fig. 11.



Fat vesicles from an emaciated subject:—1. 1. The cell-membrane. 2. 2 2. The solid portion collected as a star-like mass, with the elaine in connection with it, but not filling the cell.

The softer kinds of fat were denominated by the older anatomists *pinguedo*, lard; and the more solid, *sebum* or *sevum*, suet, tallow. Hunter distinguishes four varieties as to fluidity; oil, lard, tallow, and spermaceti. The elaine of human fat retains its fluidity at 40° F. Lard melts at 86° F.; tallow at 104° F. Spermaceti is fluid in a heat above 115° F., and solid at 112°. Oil is elaine with little or no stearine, as the neat's foot oil, obtained from the bones of the ox. In lard the stearine is in abundance, but the elaine slightly predominates. In tallow and spermaceti there is a predominance of stearine.

Ultimate analysis of Fat.—Human fat, according to Chevreul, consists of

Hydrogen	11·416
Carbon	79·000
Oxygen	9·584
	100·000

Distribution.—The adipose tissue is found very extensively in the animal kingdom. It is found in larvæ as well as in the perfect insect: also in the mollusca. It prevails in all the tribes of the vertebrata. In fish it occurs throughout the body; but in some, as the cod, whiting, haddock, and all of the ray kind, according to Hunter, it is only met with in the liver. In reptiles it exists chiefly in the abdomen. In the frog, toad, &c., it is found in the form of long appendages, like the appendices epiploicæ, situated on

each side of the spine. In birds it exists chiefly between the peritoneum and abdominal muscles; but there is also a considerable deposit in the bones of the legs, feet, last bones of the wings, and of the tail, especially of the swimming tribes, the oily principle being more abundant than in mammals. In mammalia it is very generally diffused. This class, as a whole, has the greatest quantity under the skin, and about certain of the abdominal viscera; but the hare forms a remarkable exception, it being sometimes difficult to find a particle in its whole body. It usually abounds most in the beginning of winter; and this is especially the case with the hog, and with hybernating animals, which, during their dormant state, absorb it into the system.

It is ordinarily accumulated in large masses about the kidneys, more particularly in ruminants, where it furnishes the best example of that variety of it termed suet.

Among mankind many remarkable varieties exist in regard to this tissue. Thus, in general, women are fatter than men. The healthy human fœtus, after the middle of the period of gestation, accumulates fat in considerable quantities: towards middle age, there is a similar disposition, which has not escaped ordinary observation, "Fat, fair, and forty:" in old age and decrepitude, the adipose deposit greatly diminishes.

Differences are also constantly seen in individuals, which can be referred only to an original constitutional bent. Thus young children are occasionally so overloaded with this tissue as to be unable to follow their sports; and it is not uncommon for a similar tendency to manifest itself towards the adult period, particularly in girls. In elderly persons, fat is especially prone to be accumulated over the abdomen, and between the layers of the epiploon and mesentery. Instances where it attains the thickness of three or four inches under the skin of the belly are not unfrequent in corpulent persons. A similar abundance occasions the "double chin."

It is perhaps possible for the body to grow so egregiously fat as to become lighter than water; but whether implicit faith is to be placed in the story of the Italian priest Paolo Moccia, who weighed thirty pounds less than his bulk of water, and therefore could not sink in that fluid, we do not pretend to decide. The excessive deposit of this substance constitutes a disease, which has been not very correctly called polysarcia. John Bull is celebrated for his proneness to accumulate fat: M. Blainville remarks, with *naïveté*, "We have seen many individuals of the English nation whom *embonpoint* had rendered almost monstrous; and I remember, among others, a man exhibited at the Palais Royal who weighed five hundred pounds. He was literally as broad as he was long."

Among the Hottentot women, the fat is apt to gather in the buttocks, and is considered a prominent mark of beauty; but this does not usually occur till after the first pregnancy. A somewhat analogous formation exists in a variety of sheep, (*Ovis steatopyga*, fat-buttocked sheep. *Pallas*,) reared by the pastoral tribes of Asia, in which a large mass of fat covers the buttocks and takes the place of

the tail, appearing when viewed from behind as a double hemisphere, in the notch of which the coccyx is buried, but is just perceptible to the touch. These protuberances, when very large, fluctuate from side to side, and sometimes attain the weight of thirty or forty pounds.

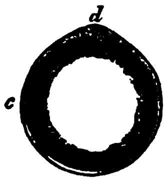
The quantity of fat in a moderately fat man is estimated by Béclard at about the twentieth of the weight of the body.

Fat is found in the following situations in the human body: in the orbits, in the cheeks, the palms of the hands and soles of the feet, at the flexures of the joints, and between the folds of the synovial membranes of joints, around the kidneys, in the mesentery and omentum, in the appendices epiploicæ, on the heart, in the subcutaneous layer of areolar tissue, but especially that of the abdomen, and of the mammary region, and in the cancelli and canals of the bones, forming the medulla. It never occurs in the areolar tissue of the scrotum and penis, or of the nymphæ, nor in that between the rectum and bladder, nor along the median line beneath the skin, nor in sundry other situations.

Fat is found in the liver, and in the brain and nerves, and occasionally in other organs. In these organs it is not enclosed in vesicles of adipose membrane, but in the elementary parts of the tissues themselves, as in the epithelium cells of the liver, and in the tubes and globules of the nervous substance.

Development of adipose tissue.—The vesicles of the adipose tissue are originally furnished with nuclei, with a central granule or nucleolus. The nucleus is situated on the inner surface of the cell-membrane, or, if this be thick, in its substance. The nucleus is speedily absorbed, and never afterwards appears. Thus it is probable that the original development-cell assumes a permanent form in the adipose vesicle.

Fig. 12.



A fat-cell, to show the nucleus; from Schwann;—c. The adipose membrane. d. The nucleus.

Formation of fat.—Many facts prove that the elements of fat are derived from the blood. All the most recent analyses of that fluid assign to it a certain proportion of both the crystalizable and the oily portion of the fat; according to Lecanu, about four parts in a thousand. In some instances, the fatty matter accumulates in the blood; cases of which have been recorded by Morgagni, Hewson, Marcet, Traill, and Babington. In such cases the serum is opaque and nearly as white as milk, and, on standing a short time, a film forms on the surface like cream. On the addition of ether, the creamy pellicle is dissolved, and the serum loses its opacity. M. Blainville relates that, in dissecting the last elephant which died at the Jardin des Plantes, he happened to wound the jugular vein, and the next morning he found that the stream of blood, which flowed from the vein, had deposited on each side a considerable quantity of a fine fatty matter, which on analysis he found to have exactly the composition of ordinary fat.

From what source is this fatty material furnished to the blood?

From fatty matters introduced into the system in the food whether in animal or vegetable substances; probably, also, from those parts of the food, which, in composition, resemble fat most nearly, such as the non-nitrogenized articles of diet, starch, gum, sugar, alcohol, beer, &c. Liebig states, that, by the separation of a small proportion of oxygen, any of these substances will present a composition similar to that of fat, and that an equivalent of starch may be changed into one of fat, by giving up one equivalent of carbonic acid, and seven equivalents of oxygen.

If, then, the system be imperfectly supplied with oxygen, while organic compounds containing carbon are furnished to it in considerable quantity, the most favourable conditions will exist for the development of fat. The oxygen required will be abstracted from the carbonized food, which, by that diminution of oxygen, will be changed into a fat. On the other hand, exercise and labour, which increase the supply of oxygen, diminish or prevent the formation of fat. "The production of fat," says Liebig, "is always a consequence of a deficient supply of oxygen, for oxygen is absolutely indispensable for the dissipation of the excess of carbon in the food. This excess of carbon, deposited in the form of fat, is never seen in the Bedouin or in the Arab of the Desert, who exhibits with pride to the traveler his lean, muscular, sinewy limbs altogether free from fat; but in prisons and gaols it appears as a puffiness in the inmates, fed, as they are, on a poor and scanty diet; it appears in the sedentary females of oriental countries; and, finally, it is produced under the well-known conditions of the fattening of domestic animals." (Liebig's *Organic Chemistry of Physiology.*)

A good illustration of those views is afforded by the carnivorous animals. In the wild state, living entirely on azotized food, and enjoying abundance of air and exercise, they are lean; but, when domesticated, living on a mixed diet, devouring a highly carbonaceous food, taking little exercise, and being imperfectly supplied with oxygen, they grow fat.

In animals that hybernate, fat is deposited in enormous quantity just prior to the hybernating period, and during that time it gradually disappears, supplying nutriment to the system, and carbon for the respiratory process. These facts were clearly ascertained, in hedgehogs, by the celebrated Dr. Jenner.

Liebig supposes that the formation of fat is attended with the development of heat, for the oxygen disengaged in this process unites with carbon derived from the same or a different source, and an amount of heat is generated proportionate to the quantity of carbonic acid thus formed. But it may be fairly questioned, whether the temperature of the body is thereby elevated, since the separation of the oxygen would be doubtless attended by a degree of cooling sufficient to neutralize the heat developed in the formation of carbonic acid.

Lastly, fat, being a bad conductor of heat, is useful for retaining it in the bodies of animals. Hence those animals that have little hair on their skins, have the greatest quantity of subcutaneous fat. This

is remarkably the case in the seal tribe, which has a large quantity of fat between the skin and its muscle, and is almost devoid of cutaneous covering; and, in man, the subcutaneous fat, which is so generally met with, even in apparently lean subjects, is doubtless a protection against cold.

The following works may be consulted on the subjects discussed in this chapter: —The treatises on General Anatomy by Bichat, Béclard, Craigie, and Henle; Hildebrandt's Anatomie, by Weber; Blainville, Leçons de Physiologie; Liebig's Organic Chemistry; Hunter's remarks on Fat, in the Catalogue of the Hunterian Museum, vol. iii. p. 2.

CHAPTER IV.

PASSIVE ORGANS OF LOCOMOTION, CONTINUED.—OF CARTILAGE AND FIBRO-CARTILAGE.

Cartilage is extensively used in the animal frame, and is one of the simplest of the textures. Like the adipose tissue, it approaches very closely in its intimate structure to the cellular tissue of vegetables.

In the development of the embryo, it is one of the first tissues to appear as a distinct structure, and it constitutes the internal skeleton in its earliest condition in the animal scale. The rudimentary skeleton of the cephalopoda consists of it; and in one class of fishes (hence termed cartilaginous, as the shark, ray, lamprey) the skeleton is entirely composed of it.

In man, and the higher animals, cartilage is employed temporarily, as a nidus for bone, in the early stages of life, and is then called *temporary* cartilage. This, at a certain period, begins to ossify, and finally disappears by being converted into bone. At one time, the greatest part, if not the whole, of the skeleton is cartilaginous; and for a considerable period after birth the extremities of the long bones are chiefly composed of cartilage, and the larger processes are connected to the shaft of the bone by this substance.

For other purposes, however, a cartilage is employed which is not prone to ossify, viz., *permanent* cartilage, and this is used either in joints (*articular* cartilage), or in the walls of cavities (*membraniform* cartilage). The articular variety is either disposed as a thin layer between two articular surfaces, and equally adherent to both, as in the synarthrodial joints (the cranial sutures, the sacro-iliac symphyses, &c.); or it forms an encrustation upon the articular ends of the bones entering into the composition of diarthrodial joints; thus, the extremities of the femur, tibia, the arm-bones, &c., are all coated with a layer of cartilage, moulded to the shape of the articular surfaces. The membraniform cartilages are not employed in connection with the locomotive mechanism, but serve to guard

the orifices of canals or passages, or to form tubes, that require to be kept permanently open; the elasticity of the material affecting this without the expenditure of any vital force. Thus we find this variety of cartilage in the external ear, in the Eustachian tube, in the nostrils and eyelids, and in the larynx, trachea, and bronchial ramifications.

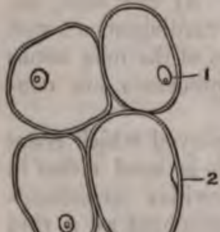
Physical characters.—Cartilage, in colour, varies from an azure, or pearly white, to a whitish yellow. The temporary and articular varieties present the former colour; the membraniform, for the most part, the latter.

Elasticity, flexibility, and considerable cohesive power are the chief physical properties of this texture; and in these qualities, and especially in the first, consists its great value, both in contributing to the perfection of the locomotive apparatus, and in its adaptation to other purposes. Cartilage is not brittle: a thin piece may be broken across by being suddenly bent at a very acute angle; but, in general, cartilage will bend easily without the occurrence of fracture, and will speedily resume its former direction on the bending force being removed.

Structure.—The simplest kind of cartilage consists merely of nucleated cells, and exceedingly resembles the cellular tissue of plants. The cells are very large, roundish or ovoidal, and more or less flattened by their mutual contact. Each has a diminutive transparent nucleus attached to the inner surface of the cell-membrane, and containing within it a minute granule, or nucleolus. We have also met with other transparent globules, of variable size and extreme delicacy, within the cells. Some white fibrous tissue usually encloses the mass of cells, and penetrates to a certain distance among the more superficial of them, which are smaller and more densely packed than the rest.

This kind of cartilage is found in the chorda dorsalis, or rudimentary spinal column of the early embryo: it also exists in the permanent chorda dorsalis of the cartilaginous fishes, and may be well seen in a thin piece of that structure from the lamprey (fig. 13).

Fig. 13.



Four nucleated cells from the Chorda Dorsalis of the Lamprey:—1. Nucleus, with nucleolus. 2. Another, seen in profile.

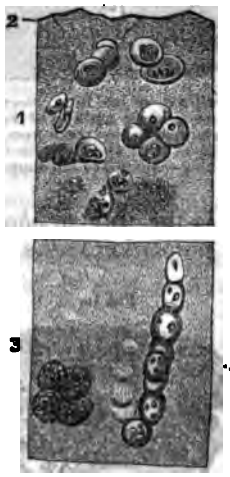
But, in other kinds of cartilage, the cells are imbedded in an *intercellular* substance, or matrix, more or less abundant in the different kinds, and presenting certain varieties of appearance. In all, it is possible to see that the cells have a proper membrane of their own, and are not mere excavations in the intercellular substance; this may often be determined at a broken edge, the cell-membrane projecting: but it is not easy to extract a cell entire, apparently on account of the delicacy of its texture, and the density of the surrounding mass.

In *temporary* cartilage the cells are very numerous, and situated at nearly equal distances apart in the intercellular substance which is

not abundant. The cells vary in shape and size, but most are round or oval. Their nuclei are for the most part minutely granular; the granules being, in some specimens, at a distance from one another. When ossification begins, the cells, which hitherto were scattered without definite arrangement, become disposed in clusters or rows, the ends of which are directed towards the ossifying part. These and other changes will be described in the chapter on bone.

In *articular* cartilage the cells are oval or roundish, often disposed in small sets of 2, 3, or 4 irregularly disseminated through a nearly homogeneous matrix, which is more abundant than in the last-named variety; fig. 14, 1. The cells measure from $\frac{1}{1500}$ to $\frac{1}{500}$ of an inch. The nuclei are for the most part small. In the interior part of the cartilages of encrustation we usually find the cells assuming more or less of a linear direction, and pointing towards the surface; fig. 14, 3. This arrangement is probably connected with a corresponding peculiarity of texture of the intercellular substance, but which it is more difficult to distinguish; for these specimens have a disposition to fracture in a regular manner along planes vertical to the surface, and the broken surface is striated in the same direction.

Fig. 14.



Articular cartilage, from the head of the Humerus:—Vertical sections: 1. Section close to the surface, 2. 3. Section far in the interior.—Magnified 320 diameters.

Near its deep or attached surface, articular cartilage blends gradually with the bone it invests. The cells in the neighbourhood, as well as their nuclei, are surrounded with a sprinkling of fine opaque granules, which seem to be a rudimentary deposit of bone. The true bone dips unevenly into the substance of the cartilage.

A pavement of nucleated epithelial particles has been described by Henle to exist on the free surface of articular cartilage. In the fœtus this may be readily seen; but in the adult we have often failed to detect it, even in perfectly fresh specimens, and notwithstanding great care. An irregularity of surface, like that represented in fig. 14, 2, often exists, and seems to show that this covering ceases when the part becomes subject to friction and pressure. Cells, too, are often seen close to this surface, and even partly projecting from it; appearances indicative of attrition.

In the *cartilages of the ribs*, which occupy an intermediate place between the articular and membraniform varieties, the cells are larger than in any other cartilage in the body, being from $\frac{1}{250}$ to $\frac{1}{430}$ of an inch in diameter. Many of them contain two or more nuclei, which are clear and transparent; and some seem to contain a few oil-globules, a condition occasionally met with in other varieties. The cells often affect a linear arrangement. The rows of them are turned in all directions, and have the appearance of having been formed by

the division of one cell, and the separation of its parts from each other. It is probable that the splitting of the nucleus may be the first step in this process, as, for example, in fig. 15, *a*.

Fig. 15.

Cartilage of the Ribs. Section showing the cells, their nuclei and nucleoli. The transparent spaces result from the removal of the cells by the knife, their cavities remaining.—Magnified 320 diameters.

The intercellular substance is very abundant in these cartilages; and though it usually presents, on a section, a very finely mottled aspect, such as is very correctly portrayed in the figure, yet we may often discern in it a most distinctly fibrous structure, in which the fibres are parallel, and which is most evident in the aged. Perhaps it would be most correct to say that these fibres are only formed by an artificial disintegration, for they are aggregated into a solid mass in the unmutilated structure. They have very little resemblance to the white fibrous tissue. It is not known whether they take any constant direction.

In the true *membraniform* cartilages, the cells are very numerous in proportion to the surrounding substance, which is consequently in small quantity. This intercellular matrix is very distinctly fibrous towards the exterior of these cartilages, and often in their interior, but with considerable variety. The thyroid and cricoid cartilages, and the rings of the trachea, seem chiefly composed of clearly defined and roundish nucleated cells, huddled together, as it were, in a promiscuous manner, fig. 16. In specimens from persons of adult age, the cells have frequently a fine granular opaque matter sprinkled on their exterior; and these, in older subjects, are seen to have become minute centres of a spurious ossification.

Fig. 16.

Thyroid cartilage:—Thin section.—Magnified 320 diameters.

In the *cartilage of the ear* the cells are small, and very close to each other; in shape they are very uniform, and vary in size from $\frac{1}{1300}$ to $\frac{1}{900}$ of an inch. A piece of this cartilage, when examined by a high power, has very much the appearance of a sieve; the holes of which are occupied by nuclei and their nucleoli. The intercellular substance is not exactly white fibrous tissue; but so nearly resembles it, especially towards the surface, as to make this form of cartilage approach fibro-cartilage more nearly than does any other.

The membraniform cartilages are invested by a layer of white fibrous tissue containing blood-vessels, and called the *perichondrium*. Its fibres are densely interwoven in all directions, and adhere intimately to the intercellular substance of the cartilage. This invest-

ment corresponds with the periosteum of bone, and in the temporary cartilages is indeed the very same structure. It is a nidus for the nutrient vessels of cartilage, and often serves to give attachment to muscles. It is best examined on the cartilages of the ribs. Its great toughness is sometimes well displayed in fractures of these cartilages, where the perichondrium remains untorn between the fragments.

The articular cartilages, which have no perichondrium, are supported and supplied with blood by the bone to which they are adapted, and by the synovial membrane, which always passes for at least some little distance over their free surface.

Vessels of cartilage.—Speaking in general terms, cartilage may be styled a non-vascular substance, for considerable masses of all its varieties exist, unpenetrated by a single vessel. The term *non-vascular*, however, it is important to observe, is to be understood in a relative sense. All tissues deriving their nutriment from blood-vessels, are, in fact, if traced up to their microscopic elements, on the outside of the channels through which the blood flows. If the quantity of vessels be large in proportion to the tissue, or if the two are mingled in an intimate manner, we term the part very vascular. If, on the other hand, there be a considerable mass of tissue, among the elementary parts of which no vessels penetrate, it is styled non-vascular. This word is not used in an absolute sense; for, if so used, it would apply equally to all tissues, except the lining membrane of the vascular system itself, which is probably nourished by the blood immediately in contact with it.

Returning from this digression, we remark, that temporary cartilage, when in small mass, is not permeated by vessels; but that, when more than about an eighth of an inch thick, it contains canals in its interior, for the transmission of vessels. These canals are somewhat tortuous, and contain a delicate extension of the perichondrium. They may be regarded as so many involutions of the outer surface of the cartilage.

The same description will apply to the various membraniform cartilages, with this difference, that their blood-vessels are less numerous. In those which are thin, no vascular canals are to be found; but where there is much substance, as in the costal cartilages, they are easily detected.

Nothing is more certain than that articular cartilage, in man, is not penetrated by blood-vessels. Coloured fluids injected into the vessels cannot be made to enter it, but are seen to turn back, on reaching it, into the tissue which conveyed them to it. But we possess a more certain test than this, in the examination of thin slices of the tissue under a high power. This brings no vessels into view: on the contrary, it proves their non-existence, beyond dispute. In some diseased states, however, the presence of a few vessels seems to have been established.

Mr. Toynbee (*Phil. Trans.*, 1841) has pointed out, that the vessels of bone, at the part on which cartilage rests, are separated from the cartilage by a bony lamella, in which no apertures exist. The

minute vessels, on approaching this lamella, seem to dilate, and then, forming arches, they run back into the cancelli of the bone. Such an arrangement must, of course, be attended with a retardation of the blood near the "articular lamella." The vessels of the synovial membrane advance with it a little way upon the articular surface of the cartilage, but only over those parts which are not subject to pressure during the natural movements of the joint. These likewise terminate in loops. In diseased states they often advance far upon the cartilage, as they do naturally, according to Mr. Toynbee's observations, during the middle period of fœtal life.

OF FIBRO-CARTILAGE.

This texture is a compound of white fibrous tissue and cartilage in varying proportions.

It is principally employed in the construction of joints, and contributes to their perfection at once by its strength and its elasticity; but as it is also, to a limited extent, used for other purposes, it may be conveniently described as, 1, Articular; 2, Non-articular.

Fibro-cartilage, examined by the naked eye, has much of the colour and general appearance of the thyroid cartilage, or of other examples of the membraniform variety, which Bichat, indeed, classed among fibro-cartilages. Its colour is white, with a slight tinge of yellow; it is interspersed by the shining fibres of white fibrous tissue, and its appearance differs with the quantity of that texture that is mingled with it. Its consistence also varies, for the same reason; in some instances being extremely dense, in others soft, yielding, and almost pulpy.

When examined microscopically, fibro-cartilage is found to consist of bundles of wavy fibres, with the cells or corpuscles of cartilage occupying the spaces formed by the interlacement of the fibrous tissue. This interlacement is often very intricate, and calculated to increase the strength of the structure in those directions in which the greatest toughness is required.

Physical and vital properties.—To the strength and density of fibrous tissue, fibro-cartilage adds the elasticity of cartilage; it is more variously flexible than the latter tissue, so that it will not crack when bent too much. Its sensibility is low, and it is devoid of vital contractility.

Vessels and nerves.—Its vessels are few, and are derived from the textures (synovial membrane or periosteum) with which it is in immediate connection. Nothing is known respecting its nerves, if indeed it possesses them.

Chemical composition.—Fibro-cartilage contains water; when deprived of it by drying, it shrivels up, and becomes hard and yellow. It yields gelatine in abundance on boiling.

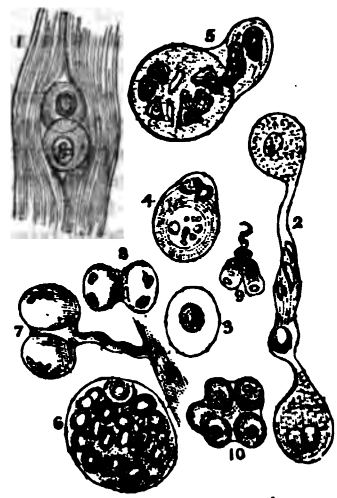
Forms of fibro-cartilage. — The *articular* fibro-cartilage is that which is found most extensively, and it exists in three forms. *a.* As *discs*, interposed between osseous surfaces, and equally adherent to

both, of which the intervertebral discs and the inter-pubic fibro-cartilage are instances. *b.* As laminæ, free on both surfaces, placed in the cavity of diarthrodial joints between the articular surfaces of the bones. These are the *menisci* of authors; they exist in the temporo-maxillary, the sterno-clavicular, and the knee-joints, and between the scaphoid and lunar, and lunar and cuneiform bones. *c.* As triangular edges to the glenoid and cotyloid cavities of the shoulder and hip joints. These are styled *circumferential.*

In examining these different forms of fibro-cartilage, some varieties are met with deserving of a brief notice.

The *intervertebral discs* consist of concentric layers of white fibrous tissue, placed vertically between the surfaces of the vertebræ: although the layers are vertical, the fibres of which each layer is composed, are directed obliquely from above downwards, and the direction of the fibres of one layer is such as to decussate with those of the layer immediately behind it. Each pair of layers of fibrous tissue is separated by a lamina of cartilage. This arrangement belongs to rather more than the outer third of the disc; the central portion is occupied by a soft, yielding, pulpy matter, which, when a disc is cut horizontally, rises up considerably above the surrounding level. This soft mass consists of a few bundles of white fibrous tissue, (wavy fibres,) with numerous nucleated cells, very variable in shape and size, loosely interspersed. It is girt by the surrounding vertical fibrous layers and their interposed cartilaginous lamellæ, and also compressed by the vertebræ between which it is placed; the pulpy matter being separated from immediate contact with the surfaces of the vertebræ by the interposition of thin layers of cartilage.

Fig. 17.



Elementary structures from an intervertebral disc:—1. Two cartilage-cells lying amongst the white fibrous tissue. The remaining objects are from the central pulpy substance; and exhibit various forms of cell. In several of these there is an appearance of multiplication by subdivision of the nucleus, and some seem attached by a fibrous tissue. The full meaning of this does not yet appear.

In the *menisci* the white fibrous tissue predominates considerably at their circumferences, while the cartilage chiefly abounds in the centre. Those of the knee-joint and temporo-maxillary joint are the densest: that of the sterno-clavicular is softer and more cartilaginous.

The *circumferential* fibro-cartilages contain a considerable predominance of fibrous tissue.

The *non-articular* form of fibro-cartilage is found deposited on the surfaces of the grooves in bones, which lodge tendons; as, for example, the groove for the lodgment of the tibialis posticus. In intimate structure it resembles the articular forms.

Reparation and reproduction.—Fibro-cartilage heals by a new substance of similar texture. Sometimes the union of bone is effected by a material of this kind, in cases where osseous union cannot be obtained.

In addition to the works on General Anatomy mentioned at the end of the last chapter, we refer to Müller's Physiology, by Baly, p. 390; the articles Cartilage and Fibro-Cartilage, in the Cyclopædia of Anatomy; and Mr. Toynbee's paper on Non-vascular Tissues, in Phil. Trans. 1841.

CHAPTER V.

PASSIVE ORGANS OF LOCOMOTION, CONTINUED.—OF BONE.

THE distinction of animal textures into hard and soft prevails very extensively throughout the animal series. The former are characterized by containing a proportion of inorganic material, in combination with animal matter, sufficient to give them that degree of hardness which is their principal physical property.

Among the invertebrated classes there are hard parts, although very differently constituted from those of the higher animals. They serve an analogous purpose,—being a basis of support for the soft parts, and in many instances a protection to them, and affording a surface of attachment for the muscles of the animal; thus playing an important part in its locomotion, or in its ordinary movements. To this category we may refer the earthy support to the soft fleshy mass, whether as an internal stem or axis, or as an external covering, which is to be found among the polypifera, performing a function similar to the skeleton of the higher animals, and composed of carbonate of lime, with a little phosphate, in combination with a small quantity of animal matter.

The calcareous plates of the star-fish and sea-urchin, (*asterias* and *echinus*,) the hard coriaceous covering of insects, the hard external integuments of crustacea, and the infinitely various shells of the gasteropoda and conchifera, must all be regarded in the light of hard parts performing the offices above referred to.

The skeleton of the higher animals is *internal;* it is clothed by the muscles and other soft parts. The first example of this arrangement is met with in the cephalopodous mollusks, in which certain cartilaginous plates are enclosed in the body of the animal, protecting certain parts of the nervous system. The skeleton of the lowest organized fishes, although much more extensive, and of a more complicated arrangement, is yet placed but little above that of those animals. It is composed of a kind of cartilage, which in its greater density, and in its having a certain quantity of calcareous deposit around it, approaches the nature of the skeleton of the higher classes.

Bone is the substance employed to form the internal skeleton of the osseous fishes, of reptiles, birds, and mammalia. It forms organs

of support, or levers for motion, or it encloses cavities affording protection to soft and vital organs.

To a superficial examination bone presents the following properties: hardness, density, a whitish colour, opacity. An examination of its physical constitution will explain these characters.

Bone contains less water than any other organ in the body; and exposure to air, even for a short time, removes the fluid by evaporation: to this, in part, may be attributed its hardness. Bone consists of an inorganic and an organic material, which may be obtained separately by very simple processes. Steep a bone in dilute mineral acid, muriatic or nitric; the earthy matter is dissolved out by the acid, and the organic substance remains, retaining the original shape and size of the bone. In fact, we obtain, by this process, the cartilaginous nidus of the bone, upon which its form depends. The vessels of the bone ramify throughout this mass; for if they have been injected, previously to the action of the acid, they will be distinctly seen ramifying through the semi-transparent animal substance. A preparation of this kind dried, and afterwards preserved in spirits of turpentine, serves beautifully to exhibit the disposition of the vessels in bone.

By subjecting a bone to a strong heat in a crucible, the animal part will be burnt out, and the earthy part will remain. Still the bone retains its form, but the cohesion between the earthy particles is extremely slight, so that the least touch will destroy its continuity; a fact which obviously points to the animal matter as affording to bone its strength of cohesion.

Bone may be deprived of its animal matter by long-continued boiling, under strong pressure, in a Papin's digester. The animal matter is extracted, in combination with water, in the form of *gelatine;* and the weight of the quantity which may thus be obtained will, owing to this union with water, exceed by three or four times that of the bone itself.

A certain proportion between these two constituents of bone is necessary to the due maintenance of its physical properties. To the earthy part it owes its hardness, its density, its little flexibility: but it is equally necessary for these properties that the animal portion shall be healthy, and in proper quantity; for the cohesion of the particles of the former is secured entirely by it. A due proportion of the animal part gives bone a certain degree of elasticity; and, were it not for the earthy matter, bones would be exceedingly flexible, as may be shown in a bone deprived of its calcareous matter by acid. Hence old bones, in which the animal matter is less abundant, as well as perhaps defective in quality, are more brittle than young ones, and old persons are more liable to fractures. But in the young, in whom the organic processes are active, and whose animal matter is fully adequate in quantity and quality to the wants of the system, the bones possess their due degree of flexibility, and hence in them fractures are less frequent; the cohesive force of the bones being sometimes so considerable, that they will bend to a great degree before yielding.

The following table from Schreger illustrates the relative proportions of the two constituents, at three periods of life, in 100 parts of bone:

	Child.	Adult.	Old.
Animal matter	47·20	20·18	12·2
Earthy matter	48·48	74·84	84·1

Or it may be stated in general terms, that in the child the earthy matter forms nearly one-half the weight of the bone, in the adult it is equal to four-fifths, and in the old subject to seven-eighths; a conclusion agreeing in the main with that drawn from the analyses of Davy, Bostock, Hatchett, and others.

It had long been known that certain bones of the body contained these constituents in other proportions than those named; for example, the petrous portion of the temporal bone had been shown by Davy to owe its stony hardness to a large proportion of earthy matter. But Dr. G. O. Rees has lately pointed out some interesting particulars as to the relative proportions of these elements in the composition of different bones.

The long bones of the extremities have, according to Dr. Rees's analysis, more earthy matter than the bones of the trunk. The bones of the upper extremity have a larger proportion of the same material than those of the corresponding bones in the lower; the humerus has more than the radius and ulna; the femur more than the tibia and fibula; while the bones of the fore-arm, as well as those of the leg, are respectively alike in constitution. The vertebræ, ribs, and clavicles are similarly constituted. The ilium has more earthy matter than the scapula or sternum; the bones of the head have more of this material than those of the trunk.

In the fœtus the same law prevails as regards the relative quantity of the earthy matter, excepting that the long bones, and the cranial bones, do not contain the excess of earthy matter which characterizes them in the adult.

The diseased state, called Rickets, so common in the children of scrofulous parents, and in the ill-nourished ones of the lower orders, consists in a deficient deposit of earthy matter; the animal matter being probably of an unhealthy quality. In this disease the bones are so flexible, that they bend under the weight that they may be called on to support, or under the action of the muscles. The lower extremities exhibit deformity first, and to the greatest degree, and the direction in which they become bent is evidently influenced by the superimposed weight; the bend almost always appears as an aggravation or the natural curves of the bones. The rickety femur has always its convexity directed forwards: the tibia is convex forwards and outwards, and the fibula follows the same direction. When the nutritive powers of the system are fully restored, the deposition of earth goes on in its healthy proportion, the animal matter becomes healthy, and the bones acquire their due degree of strength and hardness. In the tibia of a rickety child, Dr. Davy found, in 100 parts, 74 parts animal matter, and 26 earthy; and Dr. Bostock found in the vertebra of a similar subject 79·75 animal, and 20·25 earthy.

The brittleness of the bones in old age is due to an opposite cause, namely, the defective deposit of animal matter, so as to give to the earthy matter the undue preponderance already specified. But this state cannot be looked upon as morbid; it is the natural result of the feeble condition of the powers of nutrition, which ensues in the advance of years; and it will vary, in different individuals, according to the original strength of constitution of each, and according to the freedom from exposure to debilitating influences.

That state of bone which accompanies malignant disease (cancer, or fungoid disease) in adults or old persons, and which some pathologists have designated *mollities ossium*, results from the dissemination of cancerous matter through the system. In this disease the whole nutritive process of bones seems tainted; the animal part is not so much deficient in quantity, as bad in quality; the physical, as well as the vital properties of the bone are completely deranged; the osseous texture has lost its cohesive power. Hence these bones often break on the application of the slightest force, or on the feeblest exercise of the muscles. They are soft, too, in the recent state; the knife will sometimes penetrate them; and they are often pervaded by a considerable quantity of oil.

Bones possess a remarkable power of resisting decomposition. Even the animal part seems to acquire this power through its combination with the earthy. This is manifest from analyzing bones which have been long kept, or fossil bones. Cuvier states that the latter bones exhibit a considerable cartilaginous portion; and Bichat found that clavicles, which had been exposed for ten years to the wind and rain at the cemetery of Clamart, presented, under the action of acid, an abundant cartilaginous parenchyma. In an old Roman frontal bone, dug up from Pompeii, Dr. Davy found 35·5 animal parts, and 64·5 earthy; and in a tooth of the mammoth, 30·5 animal, and 69·5 earthy.

The animal part of bone consists of cartilage, with vessels, medullary membrane, and fat. The cartilage, is readily convertible into gelatine, according to Berzelius, after three hours' boiling; and, when this has been removed, there remain only four grains out of 100, which may be considered to have been composed of blood-vessels.

The earthy part of bone consists of phosphate and carbonate of lime, with a small quantity of phosphate and carbonate of magnesia. The phosphate of lime forms the principal portion of the earthy part; in 100 parts of bone Berzelius found 51·04 of this salt. It was discovered by Gahn, and the discovery announced by Scheele, that bone-earth consisted of "phosphoric acid and lime." According to Berzelius, the phosphate consists of eight atoms of lime and three atoms of phosphoric acid; but Mitscherlich regards it as composed of three atoms of lime with one of phosphoric acid (a tribasic salt). It may be formed artificially by dropping chloride of calcium into a solution of phosphate of soda. It appears as a gelatinous precipitate, which does not crystalize, and is readily soluble in acids.

The existence of fluoride of calcium in bone was announced many years ago by Berzelius; but the observations of our friend, Dr. G.

O. Rees, throw considerable doubt upon this assertion. Dr. Rees attributes the action of the supposed fluoric acid upon glass to phosphoric acid in combination with water, which, if heated on glass of inferior quality until it volatilizes, will act upon it with considerable energy. The proportion of carbonate of lime to the phosphate is small. According to Berzelius, there are 11·30 parts in 100 of bone.

We subjoin the following process, by which the qualitative analysis of bone may be readily effected:

In order to insulate the *animal matter*, digest the bone for some days in muriatic acid diluted with about thrice its bulk of water; the earthy constituents will thus be gradually removed, leaving a semi-transparent cartilaginous tissue behind.

The *earthy matters* are best examined by treating a portion of burnt bone with nitric acid, diluted with from four to six times its bulk of water; brisk effervescence ensues, proving the presence of *carbonic acid*. Filter the acid liquid after diluting it with water, and add solution of caustic ammonia as long as the precipitate at first formed continues to be redissolved by agitation; then add solution of acetate of lead till it no longer occasions any precipitate. The dense white precipitate thus produced consists of *phosphate of lead*, which melts before the blow-pipe, and on cooling assumes its characteristic crystaline structure.

Through the solution, filtered from the phosphate of lead, pass a stream of sulphuretted hydrogen to remove the excess of lead; warm the liquid, to drive off the superfluous gas, and filter: then neutralize by ammonia, and add oxalate of ammonia as long as any precipitate occurs; abundance of *oxalate of lime* will fall as a white powder.

Fig. 18.

Vertical section of the upper end of the Femur, showing the cancellated and compact tissues.

Evaporate the filtered liquid to dryness; ignite the residue, and wash with hot water; the *magnesia* will be left behind in a pure form.

In examining a section of almost any bone, we observe two varieties of osseous substance: the one dense, firm, compact, always situated on the exterior of the bone, either as a thin layer, or as a dense thick structure possessed of great strength; the other loose, reticular, spongy, enclosing spaces or cells, which communicate freely with each other, and which, being called *cancelli*, give to this kind of osseous tissue the name *cancellated*. These cells are

formed by an interlacement of numerous bony fibres and laminæ, which although to a superficial observation exhibiting an indefinite arrangement, have nevertheless, in those bones which have to support weight, a more or less perpendicular direction. The cancellated structure of bone is always situated in its interior, enclosed and protected by the compact tissue.

The relative situation of these varieties may be well seen in a vertical section of one of the long bones (fig. 18). At the *extremities*, the cancellated texture is accumulated, invested by a thin lamella of compact tissue, giving expansion and lightness to those parts of the bone. In the intermediate portion, or *shaft*, the compact tissue is highly developed, affording great strength in the situation where that quality is the most needed.

The compact external surface of bone (except on its articular aspects) is covered by a firm tough membrane, termed the *periosteum*, which, like the perichondrium investing cartilage, consists of white fibrous tissue, densely interwoven in all directions. The cancelli are filled with fat, or *medulla*, the marrow of bone. They are lined by a delicate membrane, called the *medullary membrane*, which serves to support the fat. In the shaft of the long bones the medulla is contained not in ordinary cells, but in one great canal, which occupies the centre of the shaft, the *medullary canal*. Here the medullary membrane lines the compact tissue that forms the wall of the cavity.

Both the periosteum and the medullary membrane adhere intimately to the bone. Both are abundantly supplied with blood-vessels, which, after ramifying upon them, send numerous branches into the bone. These membranes are of great importance to the nutrition of the bone, inasmuch as they support its nutrient vessels; and, if either of them be destroyed to any great extent, the part in contact with them necessarily perishes: and they not only cover the outer and inner surfaces of the bone, but also send processes, along with the vessels, into minute canals traversing the compact tissue, and are, through the medium of these, rendered continuous with one another.

The great variety of uses to which the bones are applied in the construction of the skeleton, occasions much difference of shape as well as of size. The following arrangement comprehends all these varieties, and is that commonly adopted. We classify them as, 1, Long bones; 2, Short; 3, Flat; 4, Irregular.

The *long* bones form the principal levers of the body; their length greatly exceeds their breadth and thickness. In descriptive anatomy, a long bone is divided into a shaft, or central part, and two extremities. The shaft is never perfectly straight, it is more or less curved, as in the femur; and has always an appearance as if, while yet in a soft and flexible condition, it had received a twist, and its extremities had been turned in opposite directions. This is very manifest in the femur and humerus; more especially in the latter, where the groove, in which the radial nerve runs, is just what

one might fancifully suppose to have resulted from such a cause as that above named.

The shaft is never perfectly cylindrical; although in some bones it approaches that form, in others it is prismatic. It is hollow, as already mentioned, and contains medulla. This arrangement has the advantage of making the bone very much lighter than it would have been if solid; while it is attended with no sacrifice of strength, since the central osseous substance is that which contributes least to its power of resistance.

The strength of the shaft is amply provided for by its being composed of compact tissue, of thickness proportionate to the length of the bone, and the bore of the medullary canal. In the curved bones, additional strength is obtained in the position where the bone would be most likely to yield, by increased thickness and density along its concavity. Of this provision a good example will be found in the spine of the femur,—a ridge of extremely dense bone, placed along its posterior concave surface. In the bent bones of rickety subjects which have become fully ossified, the compact tissue on the concavity of the bend acquires an enormous development.

At the extremities of the long bones the medullary canal ceases; the osseous tissue expands; and the cancellated texture takes the place of the compact substance of the shaft, and forms the whole thickness of these portions of the bone, the medulla penetrating into its cells. Here great strength is not required, but surface is needed for the articulation of the bones together, and for affording attachment to ligaments and tendons. The cancellated tissue is admirably adapted to attain this object; for, while by the looseness of its texture it readily affords an extent of surface, its lightness is such, that even a considerable bulk of it does not materially affect the weight of the bone. The surface of this texture is covered with a thin cortex of compact tissue, which is perforated by innumerable orifices for the transmission of vessels.

The long bones are the great levers of the extremities; as the bones of the thigh and leg, arm and fore-arm. Among the bones of the hand and foot are certain ones which have all the anatomical characters of the long bones, except that of length; they, may, therefore, be grouped together in a class under the name of *short* bones. These are, the metacarpal and metatarsal bones, and the phalanges of the fingers and toes.

The *flat* bones are remarkable for their slight thickness; they are composed of two thin layers of compact tissue, enclosing a layer of cancellated texture of variable thickness. Examples of this class of bone, may be found in most of those enclosing the great cavities of the body; as the bones of the cranium, the ribs, the scapula, the os innominatum, all of which will be found to possess the same essential characters.

The cranial bones present one or two peculiarities which demand a special notice. The layers of compact tissue in them are familiarly known as the *tables* of the skull: the outer one is stouter and tougher; the inner one denser and much thinner, and therefore more

brittle. The intervening structure is called the diploë; in some places it is absent, leaving a vacant space produced by the separation of the tables, and which communicates with the external air, as in the frontal sinuses: the diploë is generally a very fine cancellated texture; but, in the mastoid process of the temporal bone, it is of a much looser kind; its cancelli are larger, and instead of being occupied by medulla, as elsewhere, they communicate with the cavity of the tympanum, and are therefore always filled with air. The diploë of the cranial bones in birds is everywhere devoid of medulla, and occupied by air, which gains access to it from the tympanum.

A fourth group of bones consists of those, which seem to combine many of the offices and forms of the three preceding ones with certain characters proper to themselves. They exhibit much irregularity of shape and size; and, on this account, are called *irregular* bones. The vertebræ, the tarsal and carpal bones, certain bones of the head and face, belong to this group. Lightness, with extent of surface, is their principal character. They are composed mainly of cancellated texture, covered by a layer of compact, and here and there a portion of compact tissue, for the purpose of affording a firm bond of connection of some process to the main part of the bone; as the pedicles, uniting the laminæ to the bodies of the vertebræ.

In examining the surfaces of these different groups of bones, we are struck with the variety of projections or eminences, and of depressions, which are found upon them. These are of two kinds; articular, and non-articular. The former are destined for the formation of joints: as the head of the thigh-bone, an articular eminence; and the acetabulum, an articular depression.

The non-articular eminences chiefly serve as points of insertion for ligaments and tendons, and exhibit a great diversity of shapes, so that anatomists designate them as tuberosities, tubercles, spines, cristæ, &c. The non-articular depressions serve a similar purpose, and are equally various in form, being described as fossæ, cells, furrows, grooves, fissures, pulleys, &c.

With reference to these eminences and depressions, it may be observed that they are well marked in proportion to the muscularity of the subject. In the female, for instance, they are less distinct than in the male; in the powerfully muscular man they are at the maximum of development. As Sir Charles Bell has remarked, a person of feeble texture and indolent habits has the bone smooth, thin, and light; while with the powerful muscular frame is combined a dense and perfect texture of bone, where every spine and tubercle are well developed. And thus the inert and mechanical provisions of the bone always bear relation to the muscular power of the limb; and exercise is as necessary to the perfect constitution of a bone, as it is to the perfection of muscle. It is an interesting fact, that if a limb be disused, from paralysis, the bones waste as well as the muscles.

Of the Vessels of Bone.—We now proceed to inquire into the manner in which the nutrition of bone is provided for. A texture containing so much animal matter, and needing a constant supply of

inorganic material likewise, must necessarily be largely supplied with blood, the common source of the materials of all the tissues.

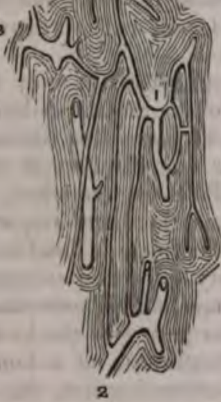
The blood-vessels of bone are very numerous, as may be satisfactorily seen on examining a well-injected specimen. The arteries are in great part continued from those of the periosteum: those which penetrate the cancellated texture of the extremities of the long bones are very large, and ramify freely among the cancelli.

The membrane of the medulla which is contained in the shaft, receives its blood from a special artery that pierces the compact tissue through a distinct canal, known as that for the nutritious artery. This vessel divides into two immediately on entering the medullary canal; of these, one ascends, the other descends, and both break up into a capillary network, anastomosing with the plexuses in the extremities of the bone, derived from the arteries that penetrate there. From the copious vascular network thus formed within the bone, the innermost part of the compact substance of the shaft receives its blood-vessels.

In the compact tissue the arteries pass into very narrow capillary canals, most of which are invisible to the naked eye. In carefully raising the periosteum from a bone that has been subjected to a little maceration, the vessels may be seen in great numbers passing from that membrane into the osseous texture, and many of the larger ones seem to be surrounded by a sheath derived from the periosteum. Similar sheaths may be seen surrounding the vessels of the cancellated texture.

The vascular canals of the compact tissue are styled *Haversian*, after their discoverer, Clopton Havers. They are disseminated pretty uniformly through the tissue, and inosculate everywhere with one another. In the long and short bones they follow the same general direction as the axis of the bone, and are joined at intervals by cross branches. The meshes thus formed are more or less oblong (fig. 19). The deeper ones open into the contiguous cancelli, with the cavities of which they are continuous.

Fig. 19.



Haversian canals, seen on a longitudinal section of the compact tissue of the shaft of one of the long bones:—1. Arterial canal. 2. Venous canal. 3. Dilatation of another venous canal.

The arteries and veins of bone usually occupy distinct Haversian canals. Of these the venous are the larger, and commonly present, at irregular intervals, and especially where two or more branches meet, pouch-like dilatations, calculated to serve as reservoirs for the blood, and to delay its escape from the tissue. In many of the large bones, particularly in the fat and irregular ones, the veins are exceedingly capacious, and occupy a series of tortuous canals of remarkable size and very characteristic appearance. These are well described by Breschet in his elaborate work on the venous system; from which

the accompanying figure (fig. 20) is taken. These canals run, for the most part, in the cancellated structure of the bones, and are lined by a more or less complete layer of compact tissue, which itself often contains minute Haversian canals. The veins they contain discharge themselves separately on the surface.

Fig. 20.

Venous canals in the diploë of the cranium.—After Breschet.

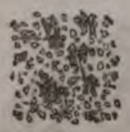
The Haversian canals vary in diameter from $\frac{1}{2500}$ to the $\frac{1}{200}$ of and inch, or more, the average being about $\frac{1}{500}$. Their ordinary distance from one another is about $\frac{1}{120}$ of an inch. They may be regarded as involutions of the surface of the bone for the purpose of allowing vessels to come into contact with it in greater abundance. It is evident that the cancelli, and even the great medullary canal itself, are likewise involutions of the osseous surface, though for a partly different end. These larger and more irregular cavities in bone may be considered as a dilated form of Haversian canals. They contain vessels not only for the nutrition of the thin osseous material forming their walls, but also for the supply of the fat enclosed within them.

Thus the true osseous substance may be described as lying in the interstices of a vascular membrane, or of a network of blood-vessels. The most interesting points in the minute anatomy of bone relate to the mode in which nutrition is provided for in those parts not in immediate contact with the blood-vessels. We have already seen that considerable masses of cartilage derive their nutriment from vessels placed on their exterior only, apparently by a kind of imbibition, perhaps aided by the presence of the nucleated cells, and by a more or less fibrous texture: but bone, which is of a far harder and denser nature, is unable to imbibe its nourishment so easily. Hence its surface is greatly augmented by the arrangements already detailed; and, in addition to this, the osseous tissue itself is provided with a special system of microscopic cavities and canaliculi, or pores, by which its recesses may be irrigated, to a degree of minuteness greatly exceeding what could have been effected by blood-vessels alone, consistently with the compactness and density required in the tissue. The study of this delicate apparatus will now demand attention, but a few words must be premised on the ultimate structure of the *osseous tissue*.

It appears from the researches of Mr. Tomes, about to be published in the Cyclopædia of Anatomy, that the ultimate structure of the osseous tissue is *granular*. The granules of bone are often very distinctly visible, without any artificial preparation, in the substance of the delicate spiculæ of the cancelli, viewed with a high power, and

in various sections of all forms of bone. They may be generall obtained in calcined bone, either by bruising a fragment of it, or b steeping it in dilute muriatic acid; they may also b made very evident by prolonged boiling in a Papin' digester. Those represented in fig. 21 were obtaine in the latter mode. The granules vary in size fro $\frac{1}{6000}$ to $\frac{1}{14000}$ of an inch. In shape they are oval c oblong, and often angular. They cohere firmly tog ther, possibly by the medium of some second sul stance. In some few instances, Mr. Tomes has m with a very minute network, which seems adapte to receive them in its interstices; but this he conside to require confirmation. A frequent appearance c the granular texture is well represented in fig. 22.

Fig. 21.



Ultimate granules of bone, isolated and in small masses, from the Femur.—(From a preparation of Mr. Tomes.) Magnified 320 diameters.

Where bone exist naturally in an exceed ingly attenuated form it may consist of a mer aggregation of thes granules, unpenetrate by any perceptibl pores. This constitute the simplest form unde which the tissue ca present itself.

Fig. 22.

Two lacunæ of osseous tissue, seen on their surfaces, showing the disposition of their pores. The granular aspect of the tissue both on their walls and around them is well represented.—Magnified 1200 diameters. Drawn from a preparation of the cancelli of the Femur made by Mr. Tomes.

But all the osseou tissue with which th human anatomist is co cerned is of such bul as to contain the seri of pores and caviti already alluded to f the conveyance of fluid from and to i vascular surface. These *pores* alwa advance into the bone from open orific on its surface. They soon arrange then selves in sets, each of which, after ana tomosing with neighbouring ones, di charges itself into a small cavity or *lacun* in which its individual pores coalesc From the sides of this lacuna other por pass off to similar cavities in the vicinit and others proceed from its opposite su face to penetrate still deeper into th tissue. These pour themselves into an ther lacuna, or divide themselves betwe two or three, which are connected in lik manner by lateral channels. From thes again pass others, which pursue an onwar course from the surface; and so on, unt

Fig. 23.

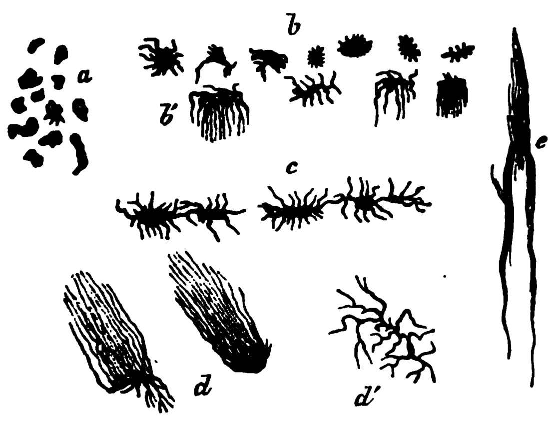
Transverse section of a part of the bone surrounding an Haversian canal, showing the pores commencing at the surface. a, anastomosing and passing from cavity to cavity.—Magnified about 300 diameters. From a preparation made by Mr. Tomes.

the whole substance of the bone is perforated by them. The pores from the further side of the extreme lacunæ either open on the surface of the bone which they may now have reached, or else take a recurved direction back into the tissue.

When this beautiful system of microscopic pores and cavities was first seen, it was not recognized as such. The lacunæ were imagined to be solid *corpuscles* (a name still commonly applied to them), and the lines radiating from them to be branching threads of the earthy constituent of bone. They may be proved in many ways, however, to be real excavations in the tissue. With a sufficiently high power their opposite walls can be distinctly seen, as well as their hollow interior; but the most conclusive evidence lies in our being able to fill them with fluid. If a dry section of bone, in which they are very apparent, be moistened with oil of turpentine while in the field of the microscope, the course of this penetrating material can be witnessed, as it advances into the tissue. It is seen to run quickly along the pores from the Haversian canals, and from the surface of the specimen, where they have been cut across. Having entered a lacuna, it suddenly extends along the pores radiating from it, and, through these, reaches other lacunæ; rendering the tissue transparent by filling up its vacuities. In parts where air has previously occupied the vacant spaces, and the turpentine cannot displace it, the characteristic appearance of minute bubbles is often present.

The *lacunæ* of osseous tissue, if examined extensively in the vertebrate class, are found of very various shapes: sometimes scarcely to be distinguished from the pores, of which they are simple fusiform dilatations; at other times large and bulky, and forming the point of junction of a great multitude of pores. Mr. Tomes has allowed us

Fig. 24.



Form of various Lacunæ, and their pores:—*a*. Simple irregular cavities, without pores; from an ossification of the pleura; *b*. from healthy bone of the human subject. *b'*. One of the outer lacunæ of an Haversian system, with the pores all bending down towards the H. canal. *c*. Other forms from human bone, showing the lateral connecting pores.

d. From the Boa. External lacunæ of an H. system, with unusually large pores dipping towards the vascular surface. *d'*. Cavity intermediate between a lacuna and a pore. *e*. Another variety from the same reptile.—From Mr. Tomes.

to represent the principal varieties which he has met with in th human subject; and some remarkable ones from the lower animal are shown (fig. 24) from the same source. In the true *dental* sub stance, which is a kind of bone, the lacunæ are almost entirely def cient, and the pores attain a very singular development, which wi be described in a subsequent chapter.

But though varieties are occasionally met with, yet, in the tru bone of man and the mammalia, the lacunæ possess a very constar form; being somewhat oval, and more or less flattened on the opposite surfaces. The two surfaces look respectively to and fro the nearest surface of the tissue, and meet in a thin edge. As pore pass off equally from all parts of the lacunæ, it follows that by fa the greater number pass to or from the surface of the bone; a arrangement admirably adapted for the transmission of the nutritiou fluids. The pores passing from the edge principally serve to connec together those lacunæ that lie at nearly the same distance from th surface. In fig. 22, the lacunæ are seen on their surface; in fig. 23 on their upper edge.

The lacunæ have an average length of $\frac{1}{1800}$ of an inch, and the are usually about half as wide, and one-third as thick. The diamete of the pores is from $\frac{1}{20000}$ to $\frac{1}{12000}$ of an inch.

The osseous tissue, thus studded by thousands of flattened lacunæ which lie for the most part in planes parallel to the surface, has decided disposition to split up into *laminæ*, following the same direc tion. This is more evident in the bones of old persons, and may b generally promoted by maceration in dilute acid. It is most apparen where the mass of material between two vascular surfaces is grea and the series of lacunæ numerous. It is probable that this lamellate structure depends in part on the mode of development and growth this tissue, and it perhaps contributes to the perfection of the nutritiv process within it.

It will now be easy to comprehend the apparently complex arrang ment of the osseous tissue in the interior of bones. Let us take, f example, one of the long bones. The entire vascular surface co sists of, 1, the *outer surface*, covered by the periosteum; 2, the *inn surface*, lined by the membrane of the medullary cavity, and of th cancelli; 3, the *Haversian surface*, or that forming the canals of th compact tissue, and having in contact with it the vascular netwo that occupies them, and which has been already described. The involutions of the surface are so arranged that no part of the osseo tissue is in general at a greater distance than $\frac{1}{170}$ of an inch from th vessels that ramify upon them.

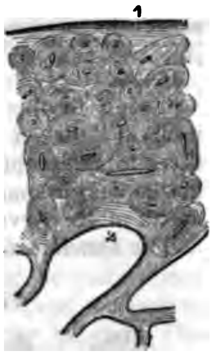
There is a layer of tissue on the exterior of the bone deriving i nourishment from the periosteum, and which may be called the *per osteal layer*. The lacunæ of this layer all face that surface, and th pores of the superficial ones open upon it. There is another laye forming the immediate wall of the medullary cavity, and termed th *medullary layer*. Its lacunæ, in like manner, face this cavity; an the pores of the inner ones open upon it. This layer becom variously folded to form the plates and fibres of the cancelli; and a

the lacunæ of these face these irregular cavities, and their pores open into them. The Haversian surface, too, being an involution of the outer and inner surfaces, and serving to connect them, is, in fact, formed by an involution of the periosteal and medullary layers, and unites these with one another. Where a vessel enters the compact tissue from the exterior, it carries with it a sheath of bone from the periosteal layer. The lacunæ of this osseous sheath, instead of being turned outwards, like those of the periosteal layer, preserve their relation to the vascular surface to which they pertain, and face *inwards* towards the vessel. Wherever the vessel penetrates, whatever direction it takes, and however it branches, it is everywhere accompanied by this sheath from the periosteal layer, or by offsets from it; and, when it enters the medullary canal, its sheath expands into the medullary layer.

The vessels of the compact tissue are so close together that the osseous sheaths respectively surrounding them come into contact and unite; and thus all the space between the outer and the inner surface of the compact tissue is filled up: thus, in a word, the compact tissue is constructed.

As the vessels of the compact tissue take a longitudinal direction, a transverse section of the bone (fig. 25) will appear pierced by numerous holes which are the Haversian canals cut across. Each hole appears as the centre of a roundish area, which is the section of an involuted periosteal layer now become a vertical rod, containing a vessel in its axis. The Haversian canals vary considerably in size, and do not maintain a very close relation to the thickness of their respective osseous walls. They are frequently eccentric, owing to their wall bulging more in one direction than another, to fit in between others in the vicinity: for though the rods of bone, containing the vessels, affect the cylindrical form, they often present an oval, or even a very irregular, figure, on a section; their close package having modified their form. The periosteal and medullary layers are also well seen on the same section, the latter curving inwards to constitute the walls of the cancelli. These two layers are of very irregular thickness, as the Haversian rods encroach on them unequally (fig. 25).

Fig. 25.



Transverse section of the compact tissue of a long bone; showing. 1. The periosteal layer. 2. The medullary layer, and the intermediate Haversian systems of lamellæ each perforated by an H. canal.—Magnified about 15 diameters.

On a further examination of such a section, with a sufficient magnifying power, we observe the lacunæ of the periosteal and medullary layers facing those surfaces, and their pores opening upon them; while the lacunæ of each Haversian layer all face the corresponding canal, and their pores radiate from it (fig. 26, and the previous fig. 23, more highly magnified). The lacunæ facing the Haversian surface are generally curved concentrically with it. They are more numerous, and their pores more abundant, on the side where there is most osse-

ous substance, and where it consequently extends furthest from the source of nutriment, the Haversian vessel. The reason of the want of proportion between the width of the canals, and the thickness of their respective osseous walls, appears to be this, that the larger canals transmit vessels to other parts, besides containing those which nourish their own layer; while some of them are, no doubt, in a great measure channels for veins.

Fig. 26.

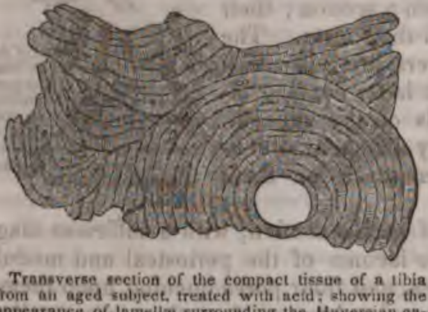
Part of the preparation represented in the last figure, more highly magnified; showing the package of the Haversian systems, and also the light spaces between neighbouring ones. The system, *a*, appears to fill up an interval between the others. The lacunæ are seen facing the Haversian canals, and their pores taking a general radiating direction. At *s*, an irregular lacuna communicates with the pores of three contiguous systems.

The outer lacunæ belonging to an Haversian canal sometimes send out pores to anastomose with those of the neighbouring rods; but this seems to happen chiefly where the contiguous rods have just sprung from a common stock. Occasionally, also, lacunæ of irregular shape (as at *s*, fig. 26) lie in the interval of two or more rods, and communicate with lacunæ of all of them; but, in general, the outermost pores of the extreme lacunæ droop back on all sides (fig. 24, *b'*, *d*), and re-enter the penultimate series of their own rod.

Owing to this arrangement, there always appears a transparent interval between contiguous rods; the pores and lacunæ not existing there to intercept the passage of the light (fig. 26). This is a remarkable circumstance, and will be illustrated when we come to speak of the development of bone.

The *lamellated* character of bone can be frequently distinguished in the periosteal, medullary, and Haversian layers; and, in general, wherever several successive series of lacunæ exist. The Haversian rods, however, are remarkably prone to exhibit this appearance, especially under the conditions previously mentioned (p. 114). Their lamellæ, however, are not concentric, as commonly described. The fissures which disclose them are indeed concentric, but they are always incomplete, never extending completely round the canal; so that the lamellæ run into one another at various points. This results from

Fig. 27.



Transverse section of the compact tissue of a tibia from an aged subject, treated with acid; showing the appearance of lamellæ surrounding the Haversian canals. Portions of several systems of lamellæ are seen. The appearance of the lacunæ, when their pores are filled with fluid, is also seen, as well as the radiation from the canals which then remains.—From Mr. Tomes.

the fact, that the lacunæ are not arranged in sets equidistant from the centre, but are scattered, as it were, independently of one another, at every possible variety of distance from the canal (figs. 23 and 27). The larger concentric cracks, which generally run through the lacunæ, seem to occur where two or three of these happen to lie nearly in the same curve. Bone is very apt to crack in the interval between the rods; and each of these rods is really so distinct from those near it, that it may be designated conveniently, for the purposes of description, as an *Haversian system of lamellæ.*

In a longitudinal section of the compact tissue of a long bone (fig. 19, p. 110) the appearance of lamellation is generally less evident, except where a longitudinal canal happens to lie exactly in the plane of section. When the Haversian canal is a little below the cut surface, it is of course covered by some of its lamellæ, the lacunæ of which directly over it are seen in face, while the lamellæ dipping in on either side, in their course round the canal, present the thin edges of their lacunæ to the observer. In the former part those pores alone are seen that proceed from the edge of the lacunæ; while in the latter those from both surfaces are seen, and of course appear much more numerous.

The description now given of the intimate texture of the compact tissue of long and short bones will apply, in all essential respects, to every other example of the compact tissue; the chief difference consisting in the direction taken by the Haversian canals, which is irregular where the tissue follows an irregular course. In general, however, the canals, with the Haversian rods forming their sheaths, run in the direction in which the tissue needs the greatest strength. Thus, in the long bones it is vertical; and in those flat bones, which have to support weight, it is also more or less vertical; while in those designed to sustain the action of forces of other kinds it is liable to corresponding variety.

So beautifully mechanical is this disposition of the Haversian systems in the compact tissue, that we need not smile at the descriptions of Gagliardi, who, with imperfect means of observation, appears to have been at least faithful in his attempts to delineate nature. The periosteal and medullary layers are true *plates* of bone, and the Haversian systems are true fibres or *pins*, all connected with one another by direct continuity of tissue, and most artfully arranged for the mechanical ends in view; and we cannot sufficiently admire the skill which has caused the means, employed for these ends, to conspire with those which were indispensable for the due nutrition of the tissue.

In the ordinary cancellated texture, each cancellus must be regarded as a little medullary cavity, containing, as it does, medulla and highly vascular medullary membrane. The plates of bone which form its walls consist of lamellæ, among which lacunæ, with their pores, are scattered; and they sometimes, when thick, contain Haversian canals. Usually, however, the pores of these laminæ communicate directly with the cavity of the cancellus to which they belong.

Nerves of Bone.—The skill of anatomists has hitherto failed to demonstrate the presence of nerves in the interior of bones. Some nerves pass through bones, but no supply strictly to the osseous matter has yet been proved. Yet there is little doubt that the vascular surface of bones is furnished with nerves: the painfulness of many affections of the periosteum, and of the medullary membrane seems to place this beyond dispute.

Development.—In the earliest period at which the skeleton can be detected among the other tissues of the embryo, it is found to consist only of a congeries of cells, constituting the simplest form of cartilage. These increase in number and in density, and become surrounded and held together by an intercellular substance in small quantity; thus forming the *temporary cartilage*, which subsequently becomes converted into bone. The temporary cartilages have the same general shape before as after their ossification; and as this process is slow, and not finally completed until adult age, they share during a considerable period in the functions of the bony skeleton.

Until the completion of the process of ossification, the temporary cartilages increase in bulk by an interstitial development of new cells. A few vessels, also, shoot into them at an early period, occupying small tortuous canals, which subsequently become obliterated.

Ossification commences in the interior of the cartilage at determinate points, hence called *points* or *centres of ossification*. From these the process advances into the surrounding substance. The period at which these points appear varies much in the different bones, and in different parts of them. The first is the clavicle, in which the primitive point appears during the fourth week; next is the lower jaw; the ribs, too, appear very early, and are completed early; next the femur, humerus, tibia, and upper jaw. The vertebræ and pelvic bones are late, as well as those of the tarsus and metatarsus. Some bones do not begin to ossify till after birth, as the patella.

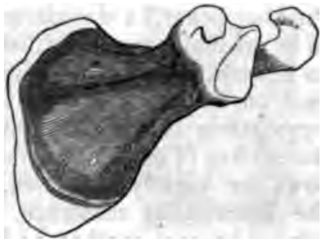
Fig. 28.

Vertical section of the knee-joint of an infant; showing the points of ossification in the shaft and epiphysis of the femur and tibia, and in the patella. A few vascular canals are also seen in the cartilage. Natural size.—From the Museum of King's College.

In most bones ossification begins at more than one point. Thus, in the long bones (fig. 28) there is a middle point, to form the future shaft; and one at each extremity, to form the articular surface and eminences. That in the shaft is the first to appear, and the others succeed it at a variable interval. The central part is termed the *diaphysis*, and for a long period after birth there remains a layer of

ified cartilage between this and the *epiphyses*, as the extremities en styled. *Processes* of bone have usually their own centres of ation, and are termed epiphyses they are finally joined to the main after which they receive the name *physes*.

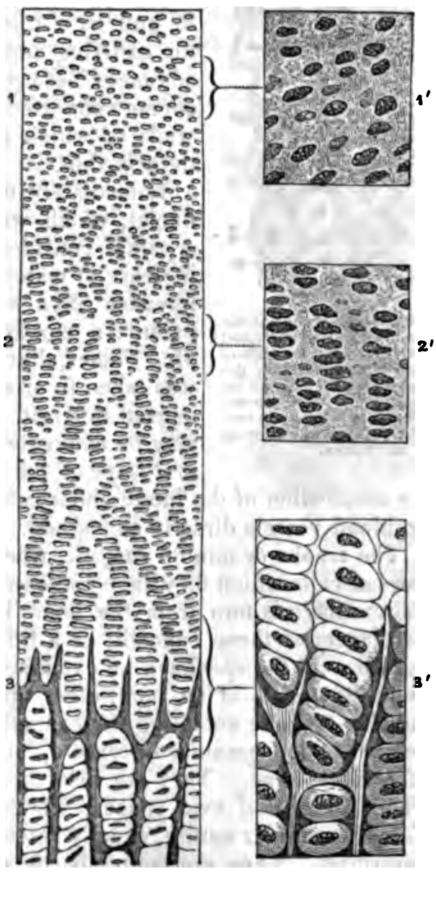
Fig. 29.



Scapula of a fœtus at the seventh month; showing the progress of ossification. Natural size. The light parts are epiphyses as yet cartilaginous.—From the Museum of King's College, London.

ification generally extends in the ion that the future laminæ and rsian rods are to assume, and corresponds in a great measure t in which it is designed that the strength of the structure may lie. , in the bones composing the of the cranium, there is always y decided radiation from the most nent part of the convexity of In the scapula this direction is ted by the lines of sharepresented in figure The outline marks the of the temporary car-, in which no other s of bone have yet appd.

Fig. 30.



e minute history of the ss by which temporary age is converted into , is of extreme interest. good descriptions of it been given by Sharpey, her, and others; from , however, it will be by the following acthat we differ in some tant particulars.

e nucleated cells of rary cartilage are small, pretty uniformly scatthrough a sparing, honeous intercellular sub-

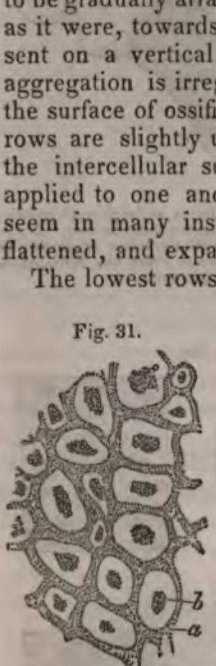
. Vertical section of cartilage surface of ossification:—1. Ordiarance of the temporary carti-. Portion of the same more highly d. 2. The cells beginning to ase linear direction. 2'. Portion gnified Opposite 3, the ossificaextending in the intercellular and the rows of cells are seen in the cavities so formed; the eing more separated than above. n of the same more highly mag-From a new-born rabbit which had served in spirit.

stance. The nuclei are granular, and large compared with the cells, which are distinguished from the surrounding substance principally by their transparency around each nucleus (fig. 30, 1. 1′).

In the vicinity of the point of ossification, (for example, in one of the long bones,) a singular change is observed. The cells are seen to be gradually arranging themselves in linear series, which run down, as it were, towards the ossifying surface. The appearance they present on a vertical section is represented in fig. 30. At first their aggregation is irregular, and the series small (2. 2′); but, nearer to the surface of ossification, they form rows of twenty or thirty. These rows are slightly undulated, and are separated from one another by the intercellular substance. The cells composing them are closely applied to one another, and compressed, so that even their nuclei seem in many instances to touch: the nuclei themselves are also flattened, and expanded laterally.

The lowest rows dip into, and rest in deep narrow cups of bone, formed by the osseous transformation of the intercellular substance between the rows. These cups are seen by a vertical section in fig. 30, 3. 3′, and by a transverse section on the level of the ossifying surface in fig. 31. As ossification advances between the rows, these cups are of course converted into closed areolæ of bone, the walls of which are lamelliform, and at first extremely thin.

Fig. 31.



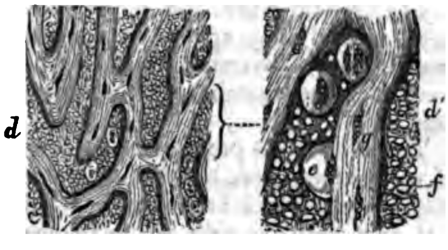
Horizontal section at the ossifying surface of a fœtal bone; showing the cups of bone cut across, with the granular nuclei of the included cells. *a* New bone. *b*. Nucleus.—From the rabbit. Taken from a drawing of Mr. Tomes.

Immediately upon the ossifying surface, the nuclei, which were before closely compressed, separate considerably from one another by the increase of material within the cells. The nuclei likewise often enlarge and become more transparent; a condition first pointed out to us by Mr. Tomes, but not present in fig. 31, which was taken from a preparation that had been immersed in spirit. The changes now enumerated may be conveniently considered to constitute the *first stage* of the process, which extends only to the ossification of the intercellular substance. In this stage there are no blood-vessels directly concerned.

The areolæ or minute *cancelli*, when first formed, contain only the rows of cells which they have enclosed. It is remarkable, that, when the cartilage is torn from the bone, it usually carries with it one or two layers of these cancelli, or a little more than is represented in fig. 30. If the specimen be examined deeper in the bone, even at a depth of $\frac{1}{10}$ or $\frac{1}{8}$ of an inch, other appearances are met with. The lamellæ of bone enclosing the cancelli are no longer simply homogeneous or finely granular in texture, but have acquired more the aspect of perfect bone. They are also thicker, and include in their substance elongated oval spaces, which, excepting that they are of a roughly granular nature, exactly resemble the *lacunæ* of bone already described. They are evidently the *nuclei* of the cells of the tempo-

rary cartilage. they are scattered at pretty uniform distances apart, and they all follow the direction of the lamellæ to which they belong (fig. 32, *d. g*). The curvilinear outline of their now ossified cells can often be partially discerned (fig. 32, *e*).

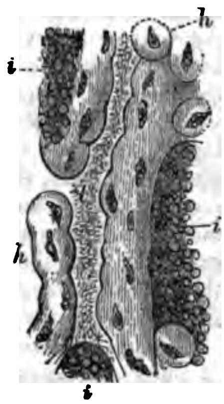
Fig. 32.



Vertical section from the same specimen as fig. 30, but deeper in the bone; showing the cancelli with blastema and a few cartilage-cells, and also the osseous laminæ containing lacunæ, similar to the nuclei of the cells:—*d*. Seen by a low power. *d'*. Portion of *d* more highly magnified. *f*. Blastema around the cartilage-cells. *e*. Cartilage-cell apposed to the wall, and its nucleus ready to become similar to the other lacunæ, as *g*.

Within the cancelli, only a few cells can be detected, these cavities being chiefly occupied by a quantity of new substance, consisting of granules, and resembling a formative *blastema* or basis, like that out of which all the tissues are evolved (fig. 32, *f*, and fig. 33, *i*). The cells that are met with are in apposition with the wall; and sometimes (as in fig. 32, *e*) one of them seems half ossified, and its nucleus about to become a lacuna. The nuclei of these cells have now always the same direction as the neighbouring lacunæ.

Fig. 33.



Another portion from the same specimen:—*i i. i*. Portion of three cancelli, containing blastema, and having between them the wall of bone. The interior of this wall, *l*, is finely granular, and contains no lacunæ, being the lamina first formed between the rows of cells in the cartilage. Coating this on both sides is a layer of bone in which the form of the cartilage-cells is still visible, as well as their nuclei forming the lacunæ. On the wall of the cancellus on the right are seen two nuclei, which appear to be forming there. This last is an appearance often seen.

In fig. 33, taken from a little deeper in the bone, we have portions of three cancelli, *i. i. i.*, together with the osseous material, now of considerable thickness, that intervenes between them. In the centre of this last is seen a lamella, *l*, of a peculiar kind, containing no lacunæ, and quite distinct from the layers, *h. h.*, between which it lies. These consist of nucleated cells, corresponding in size with those of the temporary cartilage, and having their nuclei disposed vertically, and of the same shape and dimensions as the lacunæ of bone. They are still granular, however, and no pores can be seen emerging from them. The cells are united together, and the lines of their junction have for the most part disappeared. The curvilinear border of each can be still seen, however, at its union with the central lamina, *l*. In the cancelli, *i. i. i.*, the granular blastema exists in great abundance.

It hence appears, that, after the ossification of the intercellular substance, the rows of cartilage cells arrange themselves on the inner surface of the newly formed cancelli, and become ossified, with the exception of their nuclei, which remain granular, and subse-

quently form the lacunæ of bone; and that a new substance, or blastema, appears within the cancelli, from which, probably, vessels are developed, and the future steps in the growth of the bone proceed.

The cancelli when first formed are closed cavities. At a subsequent period they appear to communicate, and thus to form the cancelli and Haversian canals of perfect bone; a complete network of blood-vessels becoming developed within them at the same time.

The subsequent progress of ossification seems to consist essentially of a slow repetition, on the entire vascular surface of the bone, of that process which has been now briefly described. It is probable that new cartilage-cells are developed on that surface, and become ossified in successive layers, their nuclei remaining to form the lacunæ, the uniform dispersion of which through bone is thus explained. The cause of the *lamination* of bone parallel to its vascular surface, is also thus illustrated.

The first appearance of pores is in the form of irregularities in the margin of the lacunæ. These increase with the consolidation of the tissue, and are converted into branching tubules which communicate with those adjacent. These pores must consequently be formed in the ossified substance of the cartilage-cells. In our account of the lacunæ of perfect bone it was mentioned, that, for the most part, those of contiguous Haversian systems do not communicate across the narrow interval that separates the Haversian rods; this interval having in fact no pores. It results from what has just been said of the mode of deposition of new layers, that the primary osseous network, formed in the intercellular substance of the temporary cartilage, must come to constitute the substance intervening between the Haversian rods, the non-porosity of which is thus satisfactorily accounted for, as well as the facility with which the rods themselves may be made to separate from one another. As for the lacunæ, their originally granular interior seems to be gradually removed, so that they become vacuities adapted for the conveyance of the nutritious fluids through the compact material of the perfect bone.

Growth of Bone.—But it must not be imagined, that, when bone is once deposited in a certain form, it thenceforward permanently maintains its size and shape. Though a lamella be completely ossified, its particles are in constant course of change, during which the most important and extensive alterations of size and figure take place in a slow and gradual manner. Thus the layers first deposited on the inner surface of the early cancelli are pushed out by the succeeding ones, and also acquire a concomitant augmentation of mass; and as, in general terms, the number of lacunæ in bone is proportioned to its amount, the early layers most likely increase by a growth and ossification of cells in their own substance, even for long after they have been pushed away from the vascular surface, and supplanted by the more recent ones. Thus, though bone grows chiefly by layers formed in succession on its vascular surface, yet it also grows in an interstitial manner after being originally deposited. It is in this way

only that we can explain the great expansion which the primary intercellular osseous network must undergo, to form that which intervenes between the Haversian systems.

Bone, when first formed, then, is disposed as an expanded surface, variously and complexly involuted, and which soon becomes covered with vessels. This is the foundation for its subsequent vascularity. and is the source also of that active power of internal growth, which has been long a theme of admiration with physiologists.

But the expansion of bone once deposited is limited. We before observed that no part of the osseous tissue was at more than a certain minute distance from the vascular surface; and that, if it were so, its nutrition could not be suitably carried on. Now, if more than a certain number of laminæ of new bone were laid down, the earlier ones would be pushed too far from the supply of blood; and hence the limitation we have spoken of. But it is necessary for bone to grow much more between the commencement of ossification and the adult age than this limitation appears to allow of; and here we come upon an admirable provision to meet this apparent difficulty.

In the *first* place, a most important process of growth is continually going on *in the cartilage*, especially near the ossifying surface, by the multiplication of the cells; and, in the latter situation, by the increase in their dimensions, occasioning that separation of their nuclei, already described (p. 119, and fig. 30, 3). In the long bones this takes place chiefly in the longitudinal direction, which is that in which growth is most active; and it continues till adult age. This fact has been long ascertained, though its real purpose appears to have been overlooked. Hales and Hunter both inserted metallic substances along the shaft of a growing bone, in a young animal, at a certain distance apart; and found after an interval of time, that the distance between them remained the same, or nearly so, while the extremities of the bone were much further apart: thus proving that the principal growth had taken place near the extremities.

Secondly, bones increase in dimensions by an accession of new *osseous* substance on their exterior; this new substance consisting not merely of new laminæ, but of new systems of laminæ, and of new involutions of the vascular surface to form new Haversian canals, so that the earlier systems of laminæ are covered over by the more recent ones. This has been best proved by the experiments with madder.

It was ascertained accidentally by Belchier that the rubia tinctorum, or madder, mixed with the food of pigs, imparted its red colour to their bones; and this circumstance has been ingeniously taken advantage of by several physiologists in the prosecution of researches on the growth of bone.* Duhamel, Hunter, and many

* The colouring of bone by madder results from an affinity of the colouring principle for the phosphate of lime. This opinion was distinctly broached by Haller (El. Phys. t. viii. p. 329), and it was subsequently proved by Rutherford, who showed it experimentally. To an infusion of madder in distilled water add muriate of lime: no change takes place. Then add phosphate of soda in solution. By double elective affinity, phosphate of lime and muriate of soda are formed. The phosphate is insoluble, and subsides in union with the colouring matter as a crimson lake. When

others, have performed multiplied experiments of this kind. In the Museum of King's College are some good preparations of bones so acted upon.

It is found that, in very young animals, a single day suffices to colour the entire skeleton, apparently in an uniform manner; in these there is no osseous material far from the vascular surface. But, if we make a transverse section of one of the long bones so treated, we observe the deepest, or even the only colour, to be really on the vascular surface; the Haversian canals are each encircled by a crimson ring. This beautiful illustration is due, as far as we know, to Mr. Tomes, who has long possessed some very elegant specimens prepared in this way.

In full-grown animals the bones are very slowly tinged, because the great mass of the bone is not in contact with blood-vessels; each Haversian system, for example, has only its small innermost lamella in contact with them; and, besides, the osseous matter is altogether more consolidated and less permeable by fluids than at a very early period of life. In the bones of half-grown animals a part of the bone is nearly in the perfect condition, while a part is new and easily coloured. Hence, it is easy in them to distinguish the new from the old by means of madder.

Now, madder given to half-grown animals colours the long bones most deeply in the interval between the shaft and extremities, and on the surface of the shaft. When madder is given at intervals, the tints in the bone are interrupted; the layers in course of formation during its administration are coloured, while those formed during the intervening periods are colourless. The long period during which bones retain the madder tinge, shows that the colouring matter is not readily resumed by the blood, from its combination with the phosphate of lime; and it seems also to indicate a sluggishness of the nutrient process in bone.

Perhaps few questions have more divided the minds of physiologists than that regarding the share taken by the periosteum in the growth and regeneration of bone; for these last are essentially the same process. We now see that bone does not grow on its exterior because the periosteum is there; and that the only part this membrane takes in the deposit of new bone is by the vascular network mingled with its fibrous tissue, and which does not differ from that on other portions of the osseous surface.

The limited expansibility of the bone already formed is the remote cause to which the growth by new deposit on the exterior is to be referred; and, in this respect, the superficial growth is strictly analogous to the exogenous mode of growth in vegetable structures.

A third mode in which increase of size is provided for, appears to be by the dilatation of the primary cancelli and Haversian canals in the central parts of the bone. In early life the cancelli are small,

madder is given as food, its colouring principle is absorbed, and circulates with the blood; and it colours first that part of the bone which is in course of formation from that fluid, or which has been last formed, *i. e.* which is nearest the vascular surface.

and there is no medullary cavity. Gradually the cancelli enlarge, and those within the shaft blend more and more with one another, by the removal to a greater or less extent of the intervening osseous walls, until at length a medullary canal is formed, around which the cancelli are very open, large and irregular. This augmentation of the vascular cavities of bone is attended with a development of adipose vesicles and their capillaries in the new space, while the proper vessels of the osseous tissue remain pretty much as before. The fat contained in the medullary canal gradually accumulates so much, that a special artery becomes enlarged to supply it, assuming the very inappropriate title of "*the* nutrient artery of the *bone*." Duhamel placed a ring of silver round a bone of a young pigeon, without injuring the periosteum. After some time, during which the bone had increased in diameter, he found the ring in the medullary canal, which had acquired a capacity equal to the previous diameter of the whole shaft.

This enlargement of the diameter of a long bone by the dilatation of its interior, is attended by two consequences, equally important. The shell of compact tissue is thus adapted to offer greater resistance to injurious mechanical forces, while the disadvantage of a corresponding increase of weight is obviated.

Reparation of Bone.—The great importance of this subject to the surgeon has led to many very interesting researches from the time of Duhamel to the present day, and by these the several steps of the process by which new bone is deposited have been ably elucidated in all that relates to their more obvious characters. When a fracture occurs, blood is, of course, effused into the wound, both from the ruptured vessels of the bone itself, and from those of the surrounding structures participating in the injury. At a short period subsequently, a semi-transparent lymph is found mingled with the coagulum, and covering the surfaces of the hard and soft parts exposed. This lymph in all probability is the same as that by which the adhesive process in other wounds is effected. In the second and third weeks a gradual condensation of this takes place, accompanied with an interstitial change, converting it into a substance resembling temporary cartilage.

Ossification takes place throughout this in a nearly uniform manner, until towards the fourth or sixth week, the whole is transformed into a spongy, but firm osseous mass, investing the exterior of the broken extremities, and extending between them in the form of a case, by which they are firmly held together. If the medullary canal has been broken across, and the broken ends evenly adjusted, there will be likewise an interior stem of new bone connecting the medullary canal of the fragments in the axis of the bone; the opposed surfaces of the compact tissue being as yet ununited. The *callus*, or new bone, thus formed, was termed by Dupuytren *provisional*, as it is gradually absorbed during the succeeding months, while the *permanent* callus is being slowly deposited between the contiguous surfaces of the compact tissue. It would appear that new bone is formed more exuberantly in the situations of the provisional callus because of their greater

vascularity; just as we may suppose the function of ordinary nutrition to be more active in those parts, than in the compact tissue of the bone. The permanent callus has all the characters of true bone.

When the reparative process in bone is interfered with, either by mal-apposition of the fragments, or by constitutional fault, a spurious union may occur by the medium of a ligamentous substance, or even a diarthrodial joint may be formed at the seat of fracture. The ends of the bones become altered in form, and adapted to one another; a kind of false capsular ligament is developed, and sometimes even an imperfect cartilage, and a lining membrane furnishing a lubricating fluid.

The following works may be consulted on Bone:—The systems of General Anatomy already quoted (p. 95); Meckel, Anat. Générale Descript. et Patholog., tom. i.; Dr. Bostock's Physiology, where will be found an excellent and learned summary of the observations of preceding physiologists on the structure and growth of bone; Mr. Paget's paper on the influence of Madder on the Bones of growing Animals, Lond. Med. Gazette. vol. xxv; Deutsch, de penitiori Ossium structurâ observationes; 1834: Miescher, de inflammatione Ossium eorumque anatome generali; 1836: Müller's Physiology by Baly, vol. i. M. Flourens has lately published a handsome volume on the growth of bone, illustrated with figures.

CHAPTER VI.

SYNOVIAL MEMBRANES.—SEROUS MEMBRANES.—VARIETIES OF JOINTS.—MECHANISM OF THE SKELETON.

The different forms of bones, when united according to various mechanical contrivances, constitute the skeleton. The framework of the body, being thus formed of several pieces jointed together, is admirably arranged for extended, or for minute and nicely adjusted motions, and for distributing concussions over a large surface. The interposition of discs, or laminæ, of elastic cartilage, or fibro-cartilage, between some bones, contributes to the latter object, by interrupting the medium through which the shock would be conducted, as well as by the elasticity of the intervening substances; and, at the same time, these discs, by their intimate adhesion to the opposed osseous surfaces, serve as powerful bonds of union between them. Joints of this kind (*synarthrodial*) enjoy a very limited degree of motion, which is entirely due to the yielding and elastic nature of the interposed material. When a greater range of motion is required than can be obtained in this way, the surfaces of the osseous segments are constructed so as to glide the one upon the other in certain directions, which are determined by the form of the articular surfaces, and by the positions at which the connecting ligaments are placed. Here the bond of union consists of the ligaments and the surrounding muscles; the osseous segments are not, as in the former instance, continuous with each other through the interposed texture,

but are separated by a space which is called the *cavity of the joint.* Each osseous surface is encrusted by a layer of articular cartilage adapted to its form, and the cavity of the joint is lined by a delicate membrane which, secretes a peculiar viscid matter, *synovia*, admirably suited to lubricate the surface. This membrane is termed *synovial*, and is constantly present in the *diarthrodial* joints.

The *articular synovial membrane* forms a closed bag, placed between the articular surfaces of the bones. Its free surface is smooth and moist; its attached surface adheres by very fine areolar tissue to the ligaments of the joint, and to the cartilages encrusting the extremities of the bones. From the ligaments it may be readily detached, and traced to the edge of the cartilage; to this it is very intimately adherent for some little distance, beyond which it cannot be followed where the cartilage has been exposed to pressure during the motions of the joint. In the fœtus it is continued over the whole cartilage (p. 97).

In some of the more complex joints the synovial membrane forms folds, which project more or less into the articular cavities, and contain fat, which Clopton Havers and other anatomists erroneously imagined to perform a glandular office, and to secrete the synovia. The knee affords some remarkable examples of these folds, in what are known as the alar ligaments.

A great number of blood-vessels are distributed in the areolar tissue upon the attached surface of the synovial membrane. In inflammation, the membrane acquires a red hue by the repletion of these vessels, and in a minute injection also it becomes coloured. Excepting in very rare cases, the vessels cannot be traced beyond the edge of the cartilage, where they form a series of loops. (See p. 99—100).

Bursæ.—A very simple form of synovial membrane is employed to facilitate the gliding of a tendon, or of the integument, over an osseous projection. It consists of a bag, generally closed at every point, connected by areolar tissue with the neighbouring parts, and secreting into its interior a fluid, which lubricates its free surface. Sometimes, when one of these bursæ exists in the neighbourhood of a large joint, it communicates freely with the cavity of its synovial membrane, as in the bursa behind the rectus femoris above the knee-joint, and that near the hip-joint behind the tendon of the psoas and iliacus muscles. These synovial sacs are found in great numbers throughout the body: some are superficial, or *subcutaneous*, such as that between the skin and the patella, or that over the great trochanter of the femur, or that over the olecranon: the *deep-seated* bursæ, however, constitute the largest proportion of them; these are almost always connected with tendons, and interposed between them and the bones over which they play. On opening a bursa, we often find its cavity traversed by bands which are either congenital and approaching to the cellular or areolar disposition, or, as seems not unlikely, of the nature of adhesions, and consequently a morbid production tending to the obliteration of its cavity.

Synovial sheaths.—These are synovial bags prolonged into the

form of sheaths, and surrounding long tendons, such as those of the flexor or extensor muscles of the fingers and toes, as they lie in their osseo-fibrous sheaths in the hand or foot. One layer of the synovial sheath adheres to the wall of the osseo-fibrous canal; the other, to the contained tendon; and, the free surface being lubricated by synovia, the tendon plays freely within the canal. In deep-seated whitlow, when the inflammation extends to one of these synovial sheaths, and gives rise to the formation of adhesions within its cavity, the motion of the tendon within is completely destroyed, and a stiff finger is the result. Similar sheaths on a larger scale envelop the tendons which pass beneath the annular ligaments of the wrist and ankle.

Synovia.—The synovial membranes, in health, contain only sufficient fluid to keep their free surfaces moist. It is, therefore, difficult to collect the synovia in sufficient quantity for examination. It is a transparent, yellowish-white fluid, viscid like the white of an egg, whence its name (συν, *cum*; ωον, *ovum*). Lassaigne and Boissel, who have published an analysis of human synovia, state that it does not coagulate spontaneously; that it is an alkaline fluid, containing albumen and salts, such as are found in the serum of the blood: and M. L'Heritier has lately analyzed two specimens of this fluid, and completely confirmed the statement of those chemists.*

It is plain, from the description above given, that synovial membranes contribute to the locomotive function by lubricating the articular surfaces, so that they may glide smoothly on one another with the least possible friction, and also by facilitating the play of some tendons over prominent surfaces, and of others within sheaths.

Serous membranes.—The movements of the viscera within the great cavities of the trunk are provided for by an arrangement similar to that described in the joints. Between the wall of the cavity and the surface of the contained viscus (the thorax and the lungs, for example,) a closed sac is placed, one layer of which is *parietal*, and the other *visceral*. These are respectively attached to the wall of the cavity and to the surface of the viscus by fine areolar tissue; and their continuity is shown at certain reflections, where the one passes into the other. The free surface, as in the synovial membranes, is continually moistened by the proper secretion, which, containing a larger proportion of water than synovia does, resembles serum of blood. The serous membranes are, the arachnoid, in the head and spine; the pleura and pericardium, in the thorax; the pericardium, in the abdomen; and the tunica vaginalis testis, in the scrotum. These are all closed at every point; so that their secretion, if morbidly increased, is retained within the cavity, and can only be removed by absorption, or by an opening through the membrane. In the healthy state, the surfaces are only moistened; and, when more fluid exists, it is the product of disease, or of post-mortem change. If the surfaces be dry, or a viscid adherent matter be effused upon them, the movements of the contained organ become impeded, and are accompanied by a peculiar sound of friction, and a vibration sensible to the hand;

* Berzelius, Chemie Organ. t. vii.

both of which are well known to physicians in the pericardium, pleura, and peritoneum, and may frequently be noticed by the patients themselves.

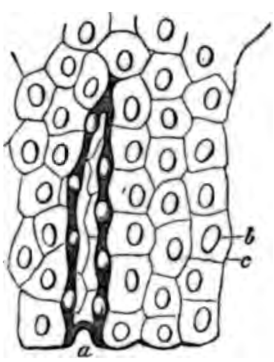
The peritoneum of the female affords a remarkable exception to the closed character of serous sacs. At two points this membrane is open, where it communicates with the canal of each Fallopian tube at its dilated extremity.

The blood-vessels of serous membranes are distributed in considerable numbers in the areolar tissue which is connected with their attached surface. We infer that nerves exist freely in the same tissue, from the intense pain which accompanies inflammation of these membranes. There is good reason to believe that lymphatics also are freely distributed in their areolar tissue.

The serous membranes connect the viscera contained in the cavities to which they respectively belong, by the folds they form as they pass from each viscus to the wall of the cavity. As the viscera in the abdomen are so many, and the folds proportionately numerous, the peritoneum is more complicated in its disposition than any other serous membrane; and it is part of the study of the descriptive anatomist to show, that the remarkable complication of folds which this membrane exhibits is not inconsistent with its adherence to the chief morphological character of serous membranes.

Microscopic characters of synovial and serous membranes.—These membranes appear to be essentially alike in their minute structure. On their free surface is a single layer of *epithelium*, the particles of which are polygonal in shape, and of transparent texture. A small fragment of this pavement, from the peritoneum of the rabbit, is represented in fig. 34. This was discovered by Henle. We have found this epithelium to rest immediately on a continuous transparent *basement membrane* of excessive tenuity, apparently identical with that which supports the epithelium of mucous membranes. Beneath this is a lamina, of *areolar tissue*, which constitutes the chief thickness of the membrane, and confers on it its strength and elasticity. This areolar tissue is traversed by a network of capillary vessels, the meshes of which are large and of rather unequal size, and by lymphatics and nervous filaments in varying number. It is of close texture, and continuous with that laxer variety by which the membrane is attached to the parts it lines.

Fig. 34.



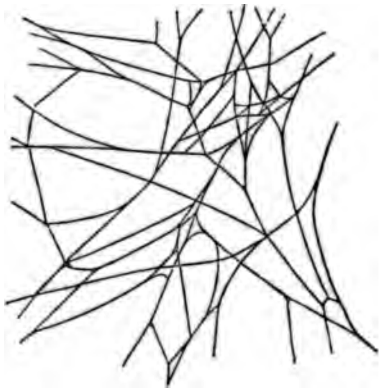
Epithelium of serous membrane:—At *a*, an accidental fold is represented, the two dark edges of which exhibit the thickness of the particles, and of their nuclei. *b*. One of the oval nuclei. *c* Line of junction between two particles.—Magnified 300 diameters.

The most favourable position for examining the areolar tissue of serous membrane, is the transparent part of the mesentery, or of any of the duplicatures of the peritoneum in small animals.

Here we observe the yellow fibrous element assuming a very beau-

tiful arrangement (fig. 35). Its filaments interlace and inosculate chiefly in a plane beneath the basement membrane, in such a manner as to confer equal elasticity in every direction. The intermediate space is occupied by the white fibrous element, disposed in wavy bands, variously intersecting, and which become straight only when the elastic threads are stretched.

Fig. 35.



Yellow fibrous element of the areolar tissue of serous membrane. From the mesentery of the Rabbit, treated with acetic acid.—Magnified 300 diameters.

Physical and vital properties.—These are precisely those of areolar tissue: the elasticity of the serous membranes is very considerable, owing to the admixture of the yellow fibrous element in the layer which forms the chief substance of the membrane. These tissues are entirely devoid of vital contractility and their sensibility is low, except in a state of acute inflammation.

These membranes exhibit, in their inflamed state, a remarkable tendency to throw out lymph on their interior, so as to cause adhesion of their opposed surfaces. Hence a frequent result of inflammation of a serous membrane is the obliteration, to a greater or less extent, of its cavity. Synovial membranes are not so prone to the adhesive inflammation as the serous are, which seems more to be accounted for by the nature of their secretion, than by any difference of their structure. The proneness of these membranes to the effusion of coagulable lymph seems to be due to the extreme tenuity of the layer of epithelium which separates the nutrient blood-vessels from the cavity of the serous membrane. The lymph effused becomes gradually converted into areolar tissue and vessels usually constituting what are termed adhesions, but sometimes forming merely a thickened condition of the membrane.

Of the joints.—A joint, or articulation, may be defined to be the union of any two segments of an animal body, through the intervention of a structure or structures different from both.

The most perfect and elaborate forms of the articulations are those which are seen in animals that possess a fully developed internal skeleton, and in none may they be studied with more advantage than in man. In the human subject, and in the vertebrated animals generally, we have indeed, particular occasion to admire the articulations as "mirabiles commissuras, et ad stabilitatem aptas et ad artus finiendos accommodatas, et ad motum, et ad omnem corporis actionem."

The textures which form the joints, are bone, cartilage, fibro-cartilage, ligaments, synovial membrane. Bone constitutes the fundamental part of all joints; ligament variously modified is employed in

all as a bond of union; but the three remaining textures are present chiefly in those joints which enjoy a free gliding motion.

In addition to the structures already named as entering intrinsically into the formation of joints, we find that the tendons and muscles, which lie in the immediate vicinity of or which surround the joints, contribute much to their strength and security. In joints of the hinge kind we generally see the anterior and posterior parts protected more or less by the tendons of muscles, and even by muscles themselves passing from one segment of a limb to another; and here it frequently happens that the tendon is bound down on the bones which form the member, by a fibrous expansion of great strength, lined by a synovial membrane of the same characters as the articular, but adapted in its form to the osseo-fibrous canal in which the tendon is placed, *e. g.*, the tendons of the fingers. The protection and strength afforded by muscles is particularly evinced in the case of the shoulder-joint, where the capsular ligament is closely embraced by four muscles, whose tendons become identified with the fibrous capsule as they go to be inserted into the bone. A muscular capsule is thus provided for the joint, by which the bones are maintained much more firmly and powerfully in apposition than they would be if kept together by an uncontractile ligamentous capsule alone; hence the elongation of the arm that occurs as a consequence of paralysis, and hence also the greater liability to luxation which exists in a debilitated state of the system. Articular or capsular muscles, thus placed, have also the effect, as it is said, of preventing the pinching of the capsule or synovial membrane between the articular extremities of the bones in the different motions of the joint.

Atmospheric pressure, exerting as it does a force of nearly fifteen pounds on the square inch, is a powerful agent in maintaining the contact of articular surfaces. This is well illustrated by the difficulty of separating the surfaces composing the hip and shoulder joints, when the surrounding ligaments are air-tight; while, on the other hand, these surfaces may be separated by the mere weight of either bone, if one of these joints be suspended in the exhausted receiver of an air-pump. In exhibiting this experiment, we find the shoulder joint shows the effects of atmospheric pressure more strikingly than the hip, for its capsule being loose, and the osseous cavity for the reception of the head of the humerus small, the pressure of the atmosphere pushes in the capsule so that it fits closely to the head of the bone. When this pressure has been removed by exhausting the receiver, the head of the humerus falls rapidly from the socket, and the ligament becomes stretched by the weight of the bone.

The joints are supplied copiously with blood, and are remarkable for the arterial anastomoses which take place about them. The best examples of these inosculations are met with around the large joints of the extremities. The parts supplied with blood are the synovial membranes, the ligaments, the fat, and the extremities of the bones; but the cartilages certainly do not contain blood-vessels.

Of the forms and classification of the joints.—It is not difficult,

by passing in review the various motions which take place between any two segments of a limb, to form an idea, *à priori*, as to the kinds and shapes of the articulations by which the segments will be united; it is only necessary not to lose sight of the fact, that in the construction of a joint regard is had not to its mobility alone, but to its security, its durability, and the safety of the neighbouring parts. We may expect to find joints varying in the *degree* of motion, from the slightest perceptible, to the freest that is compatible with the maintenance of the segments in their proper relation with each other; and also in *extent* of motion, from that which is so slight as to admit of almost no appreciable change in the position of the parts, to that which allows of the most ample variety of movement between the segments, consistent with the integrity of the articulation.

It will appear, then, that the most simple kind of articulation is that by which two parts are so united as that only the slightest appreciable degree of motion shall exist between them. This constitutes the first great division of joints—the *Synarthrosis*, where the parts are continuous, *i. e.*, not separated from each other by an intervening synovial cavity. Some anatomists consider all synarthrodial joints to be immovable; which, although not far from the truth, cannot be said to be strictly accurate. Had immobility been the object to be attained, that might have been more effectually accomplished by the fusion of the extremities of the segments together, as in anchylosis.

In the second class of joints, motion is enjoyed freely and fully: this class is designated by the term *Diarthrosis:* the segments are interrupted completely in their continuity: the extremities of the bones can only be said to be contiguous.

Synarthrosis.—The general characters of the articulations belonging to this class are, 1, that they are very limited in their motion, insomuch as to be considered by some as immovable; 2, that their surfaces are continuous, *i. e.*, without the intervention of a synovial cavity, but with that of some structure different from bone. The following varieties may be noticed among synarthrodial articulations.

a. Suture.—When the margins of two bones exhibit a series of processes and indentations (dovetailing) which are received and receive reciprocally, with a very thin cartilaginous lamina interposed, this is the ordinary kind of suture, *sutura vera*, of which three kinds are distinguished: *sutura dentata*, where the processes are long and dentiform, as in the interparietal suture of the human skull; *sutura serrata*, when the indentations and processes are small and fine like the teeth of a saw, as in the suture between the two portions of the frontal bone; *sutura limbosa*, when there is along with the dentated margins a degree of beveling of one, so that one bone rests on the other, as in the occipito-parietal suture.

When the two bones are in juxtaposition by plane but rough surfaces, the articulation is likewise said to be by suture, and this is the false suture, *sutura notha*, of which there are two kinds; *sutura squamosa*, where the beveled edge of one bone overlaps and rests upon the other, as in the temporo-parietal suture, and *harmonia*

(ἁρμόζω, *adapto*), where there is simple apposition: this last kind of articulation is met with, as Bichat observes, wherever the mechanism of the parts is alone sufficient to maintain them in their proper situation, as may be seen in the union of most of the bones of the face.

The sutures have a considerable tendency to become obliterated by age, the intervening cartilage becoming ossified; it rarely happens that the sutures are all manifest in a human skull past fifty years of age, and sometimes the obliteration takes place at a much earlier period. The frontal suture is by no means permanent; it is not often found at puberty. In birds and fishes this tendency to the obliteration of the sutures is particularly manifest.

b. Schindylesis (σχινδύλησις, *fissio;* σχίζω, *diffindo*).—This form of articulation is where a thin plate of bone is received into a space or cleft formed by the separation of two laminæ of another, as is seen in the insertion of the azygos process of the sphenoid bone into the fissure on the superior margin of the vomer; and in the articulation of the lachrymal bone with the ascending process of the superior maxillary.

c. Gomphosis (γόμφος, *clavus. Clavatio, conclavatio*). When a bone is inserted into a cavity in another, as a nail is driven into a board, or as a tree is inserted into the earth by its roots, the articulation is by gomphosis. The only example we have of it in the human subject or in quadrupeds is in the insertion of the teeth into the alveoli.

d. Amphiarthrosis.—This is a form of articulation where two plane, or mutually adapted surfaces are held together by a cartilaginous or fibro-cartilaginous lamina of considerable thickness, as well as by external ligaments. In virtue of the elasticity of the interposed cartilaginous or fibro-cartilaginous lamina, the amphiarthrosis possesses a manifest, although certainly a very limited degree of motion, and hence most systematic writers class it with the diarthrodial articulations. But it appears much more consistent to place it among the synarthrodial joints, for, 1, its anatomical characters agree precisely with those of synarthrosis; 2, the surfaces in amphiarthrosis being continuous, it would make an exception in diarthrosis were we to place it there; and, 3, its degree of motion is greater than that of suture, only because of the greater development of the interosseous substance.

The examples of this form of joint in the human body are the articulation between the bodies of the vertebræ, that between the two ossa pubis at what is called the symphysis, and that between the ilium and sacrum. Like the sutures, the amphiarthroses are liable to become obliterated in old age, by the ossification of the interosseous lamina. This is not uncommon in the interpubic, and occurs now and then in the intervertebral and sacro-iliac joints.

Diarthrosis.—Mobility is the distinguishing characteristic of this class of joints; the articular surfaces are *contiguous*, each covered by a lamina of cartilage (*diarthrodial cartilage*), having a synovial sac interposed, and in some cases two, separated by a meniscus. The

integrity of the articulation is maintained by ligaments which pass from one bone to the other. Their mechanism is much more complicated than that of synarthrodial joints, being intended not only for security, but also to give a certain direction to the motions of which they are the centre.

Before proceeding to the enumeration of the varieties of joints that come under this head, it will not be amiss to describe briefly the various motions which may take place between any two segments of a limb, and which it is the object of these joints to admit of. It is obvious that the most simple kind of motion which can exist between two plane or contiguous surfaces, is that of *gliding:* one surface glides over the other, limited by the ligaments which extend between the bones. This motion, however, is not confined to plane surfaces; it may exist evidently between contiguous surfaces, whatever their form. When two segments of a limb, placed in a direct line, or nearly so, can be brought to form an angle with each other, the motion is that of *flexion*, the restoration to the direct line is *extension*. These two motions belong to what Bichat calls *limited opposition;* the flexion and extension of the fore-arm on the arm illustrate it. Sometimes a motion of this kind takes place in four directions, indicated by two lines which cut at right angles. This is best understood by a reference to the motions which take place at the hip-joint: there it will be seen that the thigh-bone may be brought forward so as to form an angle with the trunk, *flexion*—or it may be restored, *extension;* it may be separated from the middle line of the body so as to form an angle with the lateral surface of the trunk, *abduction*—or it may be restored and made to approximate the middle line, *adduction*. It is evident that a joint, which is susceptible of these four motions, may also move in the intermediate directions. When these motions are performed rapidly, one after the other, one continuous motion appears in which the distal extremity of the bone describes a circle indicating the base of a cone whose apex is the articular extremity moving in the joint; this motion is called *circumduction*.

Rotation is simply the revolving of a bone around its axis. It is important to bear this definition in mind: through losing sight of it many anatomists have attributed rotation to a joint which really does not possess it.

The varieties of the diarthrodial joint are as follows:

a. Arthrodia.—In this species the surfaces are plane, or one is slightly concave, and the other slightly convex: the motion is that of gliding, limited in extent and direction only by the ligaments of the joint, or by some process or processes connected with the bones. The examples in men are, the articular processes of the vertebræ, the radio-carpal, carpal, carpo-metacarpal, inferior radio-ulnar, superior tibio-fibular, tarsal and tarso-metatarsal, temporo-maxillary, acromio-clavicular, and sterno-clavicular joints. This last articulation and the wrist-joint possess a greater latitude of motion than the others; the former, in consequence of the shape of its articular surfaces; each surface is convex in one diameter and concave in the other, so that the gliding that takes place in this joint is in the direction of the long and

ort diameters, which intersect each other at right angles. It is pable, therefore, of vague opposition in those lines, but certainly t in the intermediate directions, the nature of the surfaces being lculated to prevent this. The wrist owes its mobility to the laxity its ligaments, which permit it to move as well in its transverse as its antero-posterior diameters, as also in the intermediate direcns; it consequently admits of vague opposition and circumduction. ie articulation of the metacarpal bone of the thumb with the trapeım is also an arthrodia very similar to the sterno-clavicular, but with greater degree of motion. Arthrodial joints are generally provided th ligaments, placed at the extremities of the lines in the direction which the gliding motion takes place.

b. Enarthrosis.—This is a highly developed arthrodia. The convex rface assumes a globular shape, and the concavity is so much deeped as to be cup-like; hence the appellation *ball and socket.* The ll is kept in apposition with the socket by means of a capsular ligaent, which is sometimes strengthened by accessory fibres at certain rts that are likely to be much pressed upon. The best example of arthrosis is the hip-joint, and next to it the shoulder: in the latter e cavity is but imperfectly developed. All the quadrupeds have eir shoulder and hip joints on this construction, and the same coman plan is observed in the vertebrata generally whose extremities e developed. In birds and reptiles the bodies of the vertebræ are ticulated by enarthrosis.

This species of joint is capable of motion of all kinds, opposition and rcumduction being the most perfect, but rotation limited. Indeed, hat is called rotation at the hip-joint, is effected by a gliding of the ad of the femur from before backwards, and *vice versâ*, in the etabulum; it is not a rotation of the head and neck, but of the shaft, the femur.

c. Ginglymus (γιγγλυμος, *cardo*).—The articular surfaces in the nge-joint are marked with elevations and depressions which exactly into each other, so as to restrict motion in all but one direction. hey are always provided with strong lateral ligaments, which are the ief bonds of union of the articular surfaces.

The elbow and ankle joints in man are perfect ginglymi; the knee so belongs to this class, but is by no means a perfect specimen, r, in a certain position of the bones of this joint, the ligaments are relaxed as to allow a slight rotation to take place. The phalangeal ticulations, both of the fingers and toes, are ginglymi. This form joint is most extensively employed among the lower animals. In adrupeds, most of the joints of the extremities come under this ad. In amphibia and reptiles, too, there are many examples of the nge-joint. The bivalve shells of conchiferous mollusca are united a very perfect hinge, and a great number of the joints of crustacea d insects are of this form.

The true ginglymus is only susceptible of limited opposition: hence e knee-joint cannot be regarded as a perfect example; in fact, in e perfect ginglymus there is every possible provision against lateral otion.

d. Diarthrosis rotatorius.—A pivot and a ring constitute the mechanism of this form of joint. The ring is generally formed partly of bone and partly of ligament, and sometimes moves on the pivot, sometimes the pivot moves in it. The motion is evidently confined to rotation, the axis of which is the axis of the pivot.

In the human subject the best example of this articulation is that between the atlas and odontoid process of the axis or vertebra dentata. The ring is formed by a portion of the anterior arch of the atlas, completed behind by a transverse ligament. Here the atlas rotates round the odontoid process, which is the axis of motion. Another example is the superior radio-ulnar articulation: here one-fourth of the ring is formed by bone, namely, the lesser sigmoid cavity of the ulna, and the remaining three-fourths by the round ligament called the coronary ligament of the radius. In this case there is rotation as perfect as in that just mentioned; but the head of the radius rolls in the ring, and the axis of motion is the axis of the head and neck of the bone. Some anatomists consider this joint a species of ginglymus, which they designate lateral.

The terms *Symphysis*, *Synchondrosis*, *Synneurosis*, *Syssarcosis*, *Meningosis*, have been employed by anatomists to designate certain kinds of articulation, chiefly in reference to the nature of the connecting media. Symphysis, although originally employed with great extent of meaning, seems to have been in later days applied exclusively to denote the articulations of the pelvis, which we have classed under Amphiarthrosis. We pass over the other terms because they ought to be discarded from use, as only tending to encumber a vocabulary already too much crowded with difficult and unnecessary terms.

Mechanism of the skeleton.—We shall conclude this chapter with some remarks upon the mechanical disposition of the various parts of the skeleton, and their adaptation to the purposes they were destined to fulfil.

The skeleton consists of the head, trunk, and extremities.

The head is composed of a cavity, surrounded by osseous walls (*cranium*), destined to contain and protect the brain; and of an expanded portion (*the face*), with which some of the organs of the senses are connected, and upon which the features are formed. The size of the cranium affords a good clue to determine the absolute size of the brain; and the proportion of the face to it, offers a not inexact index of the relation which the intellectual faculties and the animal propensities bear to each other.*

The spheroidal form of the cranium admirably adapts it for protecting the organ which it contains against external violence. The arched form is that which possesses most strength, and offers the greatest resistance. When, says Dr. Arnott, we reflect on the strength displayed by the arched film of an egg-shell, we need not wonder at the severity of the blows which the cranium can withstand. And he adds, in reference to the former, " what hard blows of the spoon or

* See a good account of the comparative mensuration of the skull in Mr. Ward's Outlines of Human Osteology.

knife are often required to penetrate this wonderful defence of a dormant life!" And this form, which gives so much strength to the skull, favors the transmission of vibrations along its walls, and thus saves the delicate viscus enclosed by them. Thus blows inflicted upon the cranium become diffused; and sometimes the violence applied directly to the vertex is spent upon the base of the skull, and causes a fracture there.

The compound structure of the cranial bones is an important element in the architecture of the skull as a protecting case to the brain. Most of these bones are formed of two tables: the outer one is tough, strong, and fibrous; the internal table is dense and brittle, and hence called *tabula vitrea;* and there is interposed between them a spongy texture, *the diploë*, in which blood-vessels are freely distributed (fig. 20, p. 111). The varying density of these three layers evidently diminishes their power of conducting vibrations to the parts within, whilst it does not oppose the propagation of those vibrations in the direction of the layers themselves.

The manner in which the bones of the skull are united together has an evident reference to the physical properties of their inner and outer tables. The sutures are formed by the dovetailing of the outer table; the inner being cut straight, and simply placed in apposition (a layer of cartilage intervening), forming a sort of harmonia. The inner table, which is the brittle one, is not dovetailed, because its teeth would break readily; but the toughness and elasticity of the outer table fit it well for such a mechanism. On the same principle, Sir C. Bell remarks, a carpenter joins wood, which is tough and elastic, by tenon and mortise or by dovetailing; but, if pieces of glass or marble are to be joined, cement is employed for that purpose.

The principal part of the vault of the cranium is formed by the parietal bones, which rest upon the wings of the sphenoid, and upon the temporal bones: these overlap the lower borders of the parietal bones in such a way as to prevent them from starting outwards. They act on the principle of the tiebeam in the roofs of houses.

At certain exposed situations the bones experience a thickening of their structure, causing tuberosities, which are familiar to descriptive anatomists. These contribute to the strength of the roof of the skull: in front, in the frontal bone on each side of the middle line; laterally, in the parietal bones, and, behind, in the centre of the occipital bone. At this last situation two ribs, analogous to *groinings* in architecture, intersect each other: one extends from the centre of the frontal bone to the most projecting part of the occipital foramen; the other passes horizontally across the occipital bone, and terminates immediately behind the wedge-like processes which are formed by the petrous portions of the temporal bones. The occipital protuberance, which is the point of intersection of these groinings, is the "thickest and strongest part of the skull; and it is the most exposed, since it is the part of the head which would strike upon the ground when a man falls backwards." (Sir C. Bell.)

Of the Spine.—The spinal column, in man, is a vertical, elastic

pillar, expanded inferiorly where it rests upon the sacrum. It is composed of a series of light and spongy bones, between each pair of which (except the first) a compressible and elastic disc of fibro-cartilage is placed. It has a three-fold office in the human subject: first, it is the great bond of connection between all the parts of the skeleton; secondly, it forms a canal for the lodgment and protection of the spinal cord; and thirdly, it is a column of support for the head. For these purposes the spinal column requires considerable strength, as the central pillar of the trunk: it needs mobility, to adapt itself to the various attitudes and movements of the body, and elasticity, to guard the tender organ contained within it, as well as the brain, from concussion.

The strength of the spinal column is abundantly provided for in the powerful ligament which binds the bodies of the vertebræ together in front (*anterior common ligament*), and in the strong and elastic intervertebral discs, which at once connect and separate them. The degree of motion which may take place between any two vertebræ is regulated partly by the thickness of the intervertebral disc, and partly by the disposition of the joints of the articular processes. When the latter are vertical in their direction, the vertebræ are so locked in, that their movements are very much impeded; but when they approach the horizontal direction, as in the neck, the range of motion is greater. The mobility of the spine may be compared to that of a chain; between any two links of which there is but little motion, while the whole chain is abundantly pliant. This restriction of motion between each pair of vertebræ enhances the strength of the column, and affords complete protection to the spinal cord, which would speedily suffer, did any vertebra pass beyond its prescribed limits.

In the flexuous form of the spinal column, and in the connection of the vertebral laminæ by broad bands of yellow elastic ligament, we see further provision for its elasticity, in addition to that afforded by the discs of fibro-cartilage which lie between the bodies of the vertebræ. The concavity in the region of the back is doubtless intended to give full scope to the play of the important organs within the thorax; and the cervical and lumbar curves necessarily result from this, in order that the relation of the whole column to the line of gravitation of the body may be duly preserved. The triple curvature of the spine enables it to yield with less jerk than if it were a straight spring, or one that could bend only in a single direction. "It yields in the direction of its curves, and recoils, and so forms the most perfect spring, admirably calculated to carry the head without jar or injury of any kind."

The pliancy of the spinal column favours its flexion in various directions, in obedience to the action of the numerous muscles which are inserted into the vertebral processes. Nothing is more common than to see a misshapen and crooked spine produced by the predominance of action given to certain sets of muscles, through the habitual assumption of awkward attitudes: most of the curved spines which

occur in weakly females may be traced to uncorrected bad habits as their origin.*

The spine, gradually expanding at its lower part, rests upon the base of the sacrum; and the last lumbar vertebra is separated from that bone by a fibro-cartilaginous disc. The sacrum forms a wedge separating the pelvic bones, and is admirably adapted to transmit the weight of the spine to them.

Of the pelvis.—"The spinal column," to use the words of Mr. Mayo, "rests on an elastic hoop, in the extreme circumference of which on either side the deep cups are wrought which receive the heads of either thigh-bone. But this elastic hoop is not disposed vertically, but slants in such a manner, that, when we alight upon our feet, the force of the arrested motion tells in great measure on the extensor muscles of the hip."

In the articulation of the sacrum with the ossa innominata we see remarkable provision against its displacement backwards, by a force acting from above downward, the direction in which the superincumbent weight bears, or even by one acting from before backwards. This security is obtained not only by the strong ilio-sacral ligaments, which tie the bones together behind, and the cartilage, which intervenes between the ilium and sacrum, and adheres firmly to both, but also by the double wedge-like shape of the sacrum itself: for this bone is wider above than below, so that it can thereby resist the downward pressure; and it has a greater width before than behind, which enables it to oppose the pressure in front. And Mr. Ward has shown that the sacrum is also well secured against displacement *forwards*, not only by the general compactness which the sacro-iliac joints derive from their ligaments and cartilages, but also by the cuneiform character which the bone assumes about the middle of the articular surface, where the base of the wedge is turned in the opposite direction to that which it occupies either at the upper or the lower part of the articular surface.†

These provisions for the strength and security of the sacrum are of great importance to the general mechanism of the pelvis, whether we regard it as a bony girdle constructed for the transmission of the weight of the trunk to the thigh-bones, or as an osseous cavity destined to contain and protect certain important viscera.

Viewing the pelvis in the former light, we must notice the thickening of the iliac bones along either side of its upper outlet. The groinings, thus formed, terminate opposite the acetabula, and transmit the superincumbent weight, which they share with the sacrum, to each of those cavities, whence it is again transferred to the heads of the thigh-bones; they are formed of dense compact substance, which contrasts strikingly with the thin lamellated structure of the surrounding osseous tissue.

The obliquity of the pelvis has a twofold object; first, with reference to the weight from above; and, secondly, with respect to con-

* Dr. Arnott's remarks bearing upon this subject deserve a careful perusal.—See his Elements of Physics.

† We refer for further details on this subject to Mr. Ward's excellent work, p. 256.

cussions transmitted upwards by the lower limbs, in leaps, or other rapid movements. In both instances, the shock is distributed over a greater extent of surface, and is participated in by a greater number of joints, than if the pelvis were placed directly beneath the spine; for it is obvious, that, were the axis of the pelvis vertical, and the femora placed perpendicularly under it, the weight from above would bear its chief force upon the sacrum, and the concussion from below would be felt in the hip-joints alone.

In progression, the whole pelvis receives the concussions, when they proceed from above or from below. Hence the ossa pubis are united by an intervening elastic fibro-cartilage; and any disturbance of this joint during pregnancy, or in the act of parturition, occasions great difficulty to the patient in walking, or even in maintaining the erect posture.

Of the Thorax.—The thorax is a conoidal cavity, slightly flattened on its anterior aspect. It is constructed with obvious reference to lightness, elasticity, and mobility; all these qualities being requisite for its adaptation to the ever-varying movements of the organs it contains.

The walls of the chest are formed behind by the dorsal vertebræ, to which twelve ribs are articulated on each side: seven of these, the true ribs, are connected to either margin of the sternum by pieces of cartilage, which are of the same shape and breadth as the ribs themselves. The ribs are articulated by their heads and tubercles with the bodies, as well as with the transverse processes of the vertebræ, and enjoy at these points a limited gliding motion in the upward or downward direction. The direction of the true ribs is forwards, sloping downwards; the obliquity being greatest in the lowest ribs, least in the first rib. The mobility which each rib enjoys at its vertebral articulation, permits this direction to be altered by muscular action; and the ribs, under the influence of their elevator muscles, pass from the sloping to the horizontal position. By this change the dimensions of the chest are enlarged in the transverse as well as in the antero-posterior direction, for the middle curved portions of the ribs are carried outwards, and therefore brought further apart from each other; and their sternal extremities are moved forwards, accompanied by the sternum, the distance of which from the dorsal vertebræ is thereby increased. The forces, which depress the ribs, restore their planes of position to their previous oblique direction, and the two diameters of the chest to their former dimensions. It is scarcely needful to add that the elevation of the ribs accompanies inspiration, and their depression expiration.

The following happy comparison between the thorax and the pelvis is from the pen of Mr. Mayo.

"When we compare together the several regions of the trunk, we observe that it is laid out in corresponding organs, or pairs of organs, on either side of a centre, which is formed by the five lumbar vertebræ. Above the lumbar vertebræ are the dorsal; above these, the cervical: below the lumbar vertebræ are the sacral bones; below these, the coccygeal. To the dorsal vertebræ and to the sacrum, bones are articulated, which have the double office of forming a vis-

:eral cavity, and of throwing to a convenient distance from the me-ial plane the bones of the extremities. The ribs and sternum, the :lavicles and scapulæ, form, with the dorsal vertebræ, an organ strictly analogous to that formed by the ossa innominata and the sacrum. But the chest for the function of respiration requires to be continually altering its dimensions, and the upper extremity is characterized by the extent and velocity of its movements, rather than by strength: o suit both these objects, the chest and shoulder are formed of many bones, that are movable in various senses; the ribs are capable both of rotating upon their sternal and vertebral joints, and of being raised or depressed upon their vertebral joints, carrying with them the sternum: the clavicle again rolls upon the sternum, and the scapula rolls upon the convexity of the ribs. On the other hand, the pelvis, as regards the viscera, is intended merely for their support; and if, during labor, a temporary enlargement of its lower aperture is requisite, the flexibility of the joints of the os coccygis in the female skeleton, with the temporary yielding of the ligaments, affords a sufficient provision for this object: the inferior extremities again require to be articulated to a solid, unyielding platform, upon which they may poise the incumbent weight of the trunk and head. The bones of the pelvis are for these reasons few, weighty, massive, and knit together immovably. Thus accurately do the points, in which a resemblance is wanting between the chest and pelvis, preserve the analogy between these parts."

Of the Extremities.—In no part of the skeleton is the adaptation of anatomical disposition and structure to function more strikingly obvious than in the bones of the extremities.

The lower extremities form powerful pillars of support for the trunk in the erect posture. The great strength of the femur and tibia, which form the principal portion of each pillar, fit them admirably for this office; and it is interesting to notice that dense osseous tissue in each of these bones is most abundant in those situations where the greatest strain of the pressure from above is felt. This may be seen in a transverse section of either, when a dense spine of bone is found corresponding to the concave surface of each; this is most distinct in the femur, where the dense bone alluded to constitutes the *linea aspera.*

The femur is curved forward, and this incurvation gives elasticity to the bone, and aids in distributing the force of concussions. Its shaft is inclined downwards and inwards, so that the opposite femora approach each other inferiorly at the knee-joints, while they are separated by a considerable interval above. And this interval is increased by the head and neck of each femur being united to the shaft at an obtuse angle; this angle is one of about 135 degrees in the male; it is somewhat smaller in the female.

It is evident that the femur must suffer in point of strength from this mode of junction of its neck and shaft, for a bone without any bend in its axis must necessarily be more capable of resisting downward compression, than one consisting of two pieces united at an angle. But we observe here, as in other parts of the mechanism of

the human body, that the disadvantage in one respect is more than counterbalanced by certain advantages which this peculiar arrangement offers, and which could be attained in no other way; for the junction of the neck with the shaft throws the thigh-bone outwards to a certain distance, and leaves abundant room for the play of the adductor muscles: this could only be attained otherwise by greatly enlarging the pelvis in the transverse direction. And again, in the movements of the femur, much is gained; for rotation can be performed with little muscular effort by reason of the favourable leverage afforded by the neck of the bone and the trochanter major. The increased power thus given to the rotator muscles has considerable effect in walking, which is on that account performed more lightly, and without any circumduction of the limb.

It is owing to this disposition of the neck of the thigh-bone, that, when its lower extremity advances in the vertical plane, its head and neck turn on a horizontal axis; in other words, that the *angular* motion of its shaft is converted into a *rotatory* movement at the hip-joint. And from such an arrangement this great advantage results, that in the various motions or states of the joints, as extreme or partial flexion, extension, &c., the same, or very nearly the same, extent of the articulating surfaces is exposed to pressure: for, as Mr. Ward expresses it, the rotation of a hemispherical head within a socket of the same form involves no diminution of the extent of the contiguous articulating surfaces; but the angular motion of a joint of this kind throws part of the ball out of the socket, and leaves part of the socket without bearings to rest upon, so that the weight, instead of being distributed equally over the whole surface of the head, is concentrated upon that portion which remains within the cavity. (Ward, loc. cit.)

Moreover, the joint gains as regards the extent of flexion by this conversion of angular into rotatory motion, for an angular motion in the acetabulum would be readily checked by the edge of the cavity coming in contact with the neck of the bone; "whereas rotation meets no such check in the conformation of the joint itself, but may be continued indefinitely, until opposed by the tension of ligaments, or some other adventitious obstacle."

In the structure of the extremities of the femur, we find evidence of much beautiful mechanical contrivance, in the disposition of the compact tissue, and of the rods or fibres of the cancellous texture, having an obvious reference to the direction of the weight to be sustained as well as to the dispersion of concussions. The neck of the thigh-bone, having to bear considerable superincumbent weight, is strengthened on its inferior surface by an arch of compact tissue, gradually increasing in thickness as it proceeds from above downwards, and well suited by its rigidity to oppose bending; but on its upper surface the compact tissue is thin, and the reticular texture consists of somewhat arched fibres freely interwoven, running parallel to that surface, and disposed so as to present a surface to resist the direct influence of pressure (fig. 18, p. 106). The direction of the fibres of the reticular texture of the inferior part of the neck is chiefly downwards to the trochanter minor, and it seems to establish

a communication between the osseous tissue of the head of the bone, and the dense structure which forms the lower part of the neck.

The lower extremity of the femur is almost entirely composed of cancellated texture, and affords a broad surface, for articulation with the head of the tibia to form the knee-joint. As the tibia is placed vertically under it, it not only transfers the weight from above to that bone, but it is particularly exposed to suffer from concussions conveyed upwards by the tibia. Its structure seems disposed so as to facilitate the dispersion of such concussions, the sides of the condyles projecting considerably beyond the surface of the shaft of the bone, and there being but little continuity of tissue between it and the lower end of the bone.

Of the bones of the leg, the tibia, from its strength and size, is evidently that which is destined to support the thigh; the fibula must be regarded as entirely accessory in its office, affording attachment to the interosseous ligament, and forming a greater extent of surface for the origin of muscles. By its lower extremity it supports the ankle-joint on the outside.

The tibia rests upon the astragalus, and through that bone transmits the weight to the foot. The length of this organ, its breadth, and its arched form, adapt it as a basis of support for the body in the erect posture, and as an instrument of locomotion. It obtains elasticity, and a certain amount of mobility, from its being composed of several small and light bones articulated together. These bones, although almost entirely composed of reticular texture, possess considerable power of resistance to direct pressure in those directions in which the strain would chiefly bear in the movements of the organ, and this is to be attributed to the direction of the fibres of their cancellous tissue. The principal elasticity of the foot is longitudinal, by reason of its arch being in that direction, resting upon the heel behind, and on the toes in front; but it also yields somewhat in the transverse direction, or that of the arch formed by the cuneiform bones. The extension of the os calcis backwards not only adds to the length of the longitudinal arch, but it also affords a considerable leverage to the muscles of the calf of the leg.

Upper Extremity.—The disposition and structure of the bones of the upper extremity afford a marked contrast to those of the lower. The latter are organs of support, and therefore are solid, firm, strong, and, withal, elastic. The former are destined to perform extended motions, as well as minute and nicely adjusted ones; and, therefore, while they possess all the requisite strength, they are light, present little expanse of surface, and are articulated by numerous very movable articulations.

The scapula and clavicle are the media through which the bones of the arm are united to the trunk. The former bone is remarkably thin and light, and seems little more than a surface of attachment for various muscles, on whose actions the extensive movements of the arm depend. By the clavicle it is connected to the sternum, through the sterno-clavicular articulation, the movements of which, although occurring only in two planes, intersecting each other at right angles,

are such as to favour a wide range of motion in the shoulder. So necessary is this joint to the general movements of the shoulder, that any injury or disease of it, or of the bone itself, shows itself speedily in the impediment offered to those movements. And the law of the development of this bone in the lower animals is clearly connected with a necessity for a wide range of motion in the anterior extremity. In those animals that employ the anterior extremity only as an instrument of progressive motion, there is no clavicle; hence this bone is absent from the skeletons of Pachydermata, Ruminantia, Solipeda, and the motions of the shoulder are only such as may be required for the flexion and extension of the limb. In the Carnivora, where there is a slight increase in the range of motion of the anterior extremities, a rudimentary clavicle exists; and in this class we observe that the size of the bone bears a direct relation to the extent of motion enjoyed by the limb. Thus it is smallest in the dogs, and largest in the cats: in these animals it has no attachment to either the sternum or the scapula, but is enclosed in the flesh, and does not occupy much more than half the space between the two bones last named. "But however imperfect," says Sir C. Bell, "it marks a correspondence in the bones of the shoulder to those of the arm and paw, and the extent of the motion enjoyed. When the bear stands up, we perceive, by his ungainly attitude, and the motion of his paws, that there must be a wide difference in the bones of his upper extremity from those of the ruminant or soliped; he can take the keeper's hat from his head, and hold it; he can hug an animal to death. The ant-bear, especially, as he is deficient in teeth, possesses extraordinary power of hugging with his great paws; and, although harmless in disposition, he can squeeze his enemy, the jaguar, to death. These actions, and the powers of climbing, result from the structure of the shoulder, or from possessing a collar bone, however imperfect." (Bridgewater Treatise, p. 48.)

In those Mammalia that dig and burrow in the ground, or whose anterior extremities are so modified as to aid them in flight, or which are skillful in seizing upon and holding objects with their paws, the clavicle is fully developed, and extends the whole way from the scapula to the sternum. Thus in the Rodentia this bone is very perfect, as, for example, the squirrel, the beaver, the rabbit, the rat, &c. The bat affords an example of a very strong and long clavicle, as also do the mole and the hedgehog among the Insectivora.

Among the Edentata those tribes possess a clavicle whose habits are fossorial, as the ant-eater, the armadillo, and even the gigantic extinct megatherium. In the Quadrumana the clavicles are strong, and curved, as in the human subject.

The clavicle possesses considerable elasticity by reason of its curves; a property obviously of the greatest importance to it, because, as the bond of connection of the shoulder to the trunk, it is liable to participate in the many concussions to which the upper extremity is exposed. This point has been put to the test of direct experiment by Mr. Ward. He employed the clavicle of a well-developed male subject, of the middle age: this was placed upon a smooth surface, with its shaft

perpendicular to the plane of a wall, against which its inner extremity rested; a smart blow was then struck with a hammer on the outer extremity of the bone in the direction of its long axis; the hammer rebounded from the end of the bone, which sprang to a distance of nearly two feet from the wall.

The humerus is the principal lever of the upper extremity: in man it is light, and its articular extremities are constructed to contribute to the formation of very movable joints. The bones of the fore-arm are also remarkable for their lightness and elasticity; and they move freely, not only on the humerus, but on each other. The movements of pronation and supination, which are necessary to the free and full use of the hand, are performed by the rotation of the radius round an axis passing through its head and neck; the slight curve in the shaft of the radius causes its carpal extremity to pass through a considerable space during the rotation of the forearm.

The contrast between the solidity and elastic firmness of the foot, and the lightness, flexibility and mobility of the hand, is most striking. The analogy between the anatomical elements of both organs is complete: but they are modified to suit the office for which each is destined; the foot as a basis of support, the hand as a prehensile organ. The hand is modified remarkably from the form of the foot by the divergence of the outer metacarpal bone, to form the thumb: this bone at its articulation with the carpus enjoys a considerable degree of mobility, in virtue of which exists the opposable faculty of the thumb; a power which, in a state of perfection, is peculiar to the human hand.

While the hand is so remarkably mobile, it is well protected against the effects of compression, or concussion, by the number of its joints, and the interposed cartilages and fibro-cartilages, and the soft covering of fat which lies beneath the skin of the palm; and its strength is abundantly provided for in the strong ligaments which connect the bones to each other, and the fibrous expansions which cover them.

One of the most wonderful circumstances in the construction of the hand, is its adaptability to an infinite number of offices. A powerful organ of prehension, it is yet capable of adjusting the finest pieces of mechanism, or of exposing to view the minutest wonders of nature: an admirable and most delicate instrument of touch, it may nevertheless be employed as a fearful and deadly weapon of offence: at one time it may be used to lift great weights, to pull at the cable, or to turn the windlass; and, again, it will execute the most varied and rapid movements, in the performance of works or artifices which human talent has invented.

The hand is the obedient minister of man's volition and of his genius, and, too often, the blind slave of his emotions and his passions.

The following references are subjoined:—The various treatises on General Anatomy; the article Articulation, in the Cyclopædia of Anatomy and Physiology; Mayo's Physiology, chap. xi.; Bell's Animal Mechanics; Arnott's Elements of Physics, vol. i. p. 218; Anatomie Descriptive, par Bichat, t. i.; Outlines of Human Osteology, by

F. O. Ward, a work to be strongly recommended. as well for its exact and clear descriptions, as for the excellent and original views on the mechanism of the skeleton, with which it abounds. We shall be glad to see it published in a form more suitable to its great merit.

CHAPTER VII.

ACTIVE ORGANS OF LOCOMOTION.—OF MUSCLE.—MUSCLE WITH STRIPED FIBRES—MUSCLE WITH UNSTRIPED FIBRES.—MUSCULAR ACTION.—ATTITUDES AND MOVEMENTS OF THE FRAME.

THE principal movements of the body, and all those by which locomotion is effected, are performed by means of a tissue termed *muscle*, endowed with the power of contracting, and consisting, chemically, of fibrine. This substance is arranged in the form of unbranched fibres of definite size and structure, and which, when examined under a high magnifying power, are found to be of two kinds, distinguishable from one another by the presence or absence of very close and minute transverse bars or stripes. The fibres of the *voluntary* muscles, (or those whose movements can be either excited or controlled by volition,) as well as the fibres of the heart, and some of those of the œsophagus, are *striped;* while all other muscles, including those of the alimentary canal, the uterus, and bladder, all of which are *involuntary*, are *unstriped.*

The elementary fibres of the voluntary muscles are connected to one another by areolar tissue, and arranged in sets parallel to one another. They are supplied with vessels and nerves, which lie in the intervals between them; and are attached, by their extremities, through the medium of tendon, aponeurosis, or some form of the fibrous tissue, to the parts which they are destined to move. They form organs, for the most part solid and elongated, but which are sometimes expanded into a membranous shape.

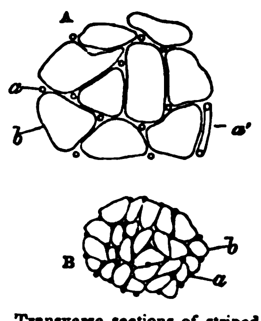
The sets of fibres of the involuntary muscles, on the other hand, usually cross each other at various angles, and interlace, and they are always arranged as membranous organs enclosing a cavity, which their contraction serves to constrict. The heart, besides being independent of the will, agrees in both these anatomical characters with the involuntary muscles, and is only allied to the voluntary by the presence in its fibres of the transverse stripes.

We shall commence with a description of the two forms of fibre.

Of the striped fibres.—The length of these is usually about that of the muscle to which they belong, but occasionally they are interrupted by tendinous intersections, as in the rectus abdominis and semitendinosus; and it is very common for them to fall short of the length of the whole organ, in consequence of an oblique disposition, as seen in penniform muscles. In the sartorius they often exceed two feet in length, while in the stapedius they are not two lines. They vary in

diameter from $\frac{1}{60}$ to $\frac{1}{1300}$ of an inch, being largest in crustacea; fish and reptiles, where their irritability is enduring; and smallest in birds, where it is most evanescent. The individual fibres, however, vary considerably in thickness in the members of the several tribes, and even in the same animal and muscle. Their average width in man is about $\frac{1}{400}$ of an inch. They are not cylindrical, but flattened more or less, by being closely packed together. This may be ascertained in the recent state, or still better by a transverse section of a dried muscle. Small interspaces are left, however, for the passage of the capillary blood-vessels along the angles of junction, and sometimes between the contiguous sides. (Fig. 36.)

Fig. 36.

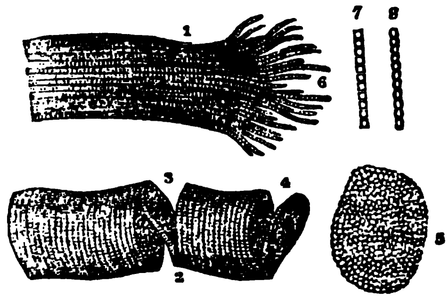


Transverse sections of striped muscle that had been injected and dried, magnified 70 diameters:—A. From the Frog. B. From the Dog. *b. b.* Section of elementary fibres, showing their angular form and various size. *a. a.* Sections of the injected capillaries, showing the position they occupy among the fibres. *a'*. Transverse branch between two longitudinal capillaries. These figures show the greater vascularity of the muscle, with the narrower elementary fibres.

Internal structure.—The beautiful cross-markings on the voluntary fibre have been known from the early days of microscopical research, and have given occasion to a variety of hypothetical and generally mechanical solutions of the problem of contraction; which, by warping the minds of observers, have had the effect of greatly complicating an already difficult subject, that of the internal anatomy of the fibre, which can only be determined by pure observation. Fontana alone among the older anatomists abstained from vague speculation; and he arrived nearest to the truth. He found that the fibre was apt to split up into fine fibrillæ, each of which was a series of particles; and he imagined that the transverse lines were caused by the regular apposition side by side of the particles of the contiguous fibrillæ. It was customary both before and since his time, as at the present day, to regard the fibre as a bundle of smaller ones, whence the term *primitive fasciculus*, first given to it by him and adopted by Müller: but this view of the subject is imperfect. The fibre always presents, upon and within it, longitudinal dark lines, along which it will generally split up into fibrillæ; but it is by a fracture alone that such fibrillæ are obtained. They do not exist as such in the fibre. And, further, it occasionally happens that no disposition whatever is shown to this longitudinal cleavage; but that, on the contrary, violence causes a separation along the transverse dark lines, which always intersect the fibre in a plane perpendicular to its axis. By such a cleavage, discs, and not fibrillæ, are obtained; and this cleavage is just as natural, though less frequent than the former. Hence it is as proper to say that the fibre is a pile of discs, as that it is a bundle of fibrillæ: but, in fact, it is neither the one nor the other, but a mass in whose structure there is an intimation of the existence of both, and a tendency to cleave in the two directions. If there were a general disintegration along all the lines in both directions, there would result a series of particles, which may be termed *primitive particles* or *sarcous elements*,

the union of which constitutes the mass of the fibre. These elementary particles are arranged and united together in the two directions.

Fig. 37.



Fragments of striped elementary fibres, showing a cleavage in opposite directions; magnified 300 diameters:—1. Longitudinal cleavage. The longitudinal and transverse lines are both seen Some longitudinal lines are darker and wider than the rest, and are not continuous from end to end: this results from partial separation of the fibrillæ. 6. Fibrillæ, separated from one another by violence at the broken end of the fibre, and marked by transverse lines equal in width to those on the fibre 7, 8, represent two appearances commonly presented by the separated single fibrillæ. (More highly magnified.) At 7, the borders and transverse lines are all perfectly rectilinear, and the included spaces perfectly rectangular. At 8, the borders are scalloped, the spaces bead-like. When most distinct and definite, the fibrilla presents the former of these appearances.—2. Transverse cleavage. The longitudinal lines are scarcely visible. 3. Incomplete fracture following the opposite surface of a disc, which stretches across the interval and retains the two fragments in connection. The edges and surface of this disc are seen to be minutely granular, the granules corresponding in size to the thickness of the disc, and to the distance between the faint longitudinal lines. 4. Another disc nearly detached. 5. Detached disc more highly magnified, showing the sarcous elements

All the resulting discs as well as fibrillæ are equal to one another in size, and contain an equal number of particles. The same particles compose both. To detach an entire fibrilla is to abstract a particle of every disc, and *vice versâ*. The width of the fibre is therefore uniform, and is equal to the diameter of any one of the discs. Its length is the length of any one of its fibrillæ, and is liable to the greatest variety.

Müller, Schwann, Lauth, and others, consider, with us, that the cross stripes of the fibre are formed by the apposition side by side of the dark points seen on the separated fibrillæ; but some believe these stripes to be present only on the surface of the fibre, and to be formed by the spiral windings of a filament. Considerable diversity of opinion also exists as to the nature of the alternate light and dark points seen on the individual fibrillæ; some conceiving them to indicate a single spiral, others a double spiral arrangement; some imagining them to be minute zigzag bendings, others indentations, and others still that they depend on the alteration of two kinds of substance. On this account we shall explain in a few words our reason for adopting the view above summarily given. A soft mass made up of an immense congeries of highly refracting particles cannot but exhibit many deceptive appearances when viewed by transmitted light, and through glasses of bad defining power. The slightest disturbance of its interior structure will affect the refractions, which will thus be readily made to disguise and modify the true form and arrangement of its integrant parts; on which account great care and circumspection, and

a total freedom from bias, are requisite for an observer who would not be misled to mistake appearances for realities.

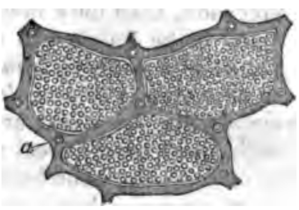
That the stripes are not caused by a structure distinct from the fibrillæ, and present only on the surface of the fibre, is evident from the following facts:

1. That a transverse section of a fibre shows it to be solid, and not hollow; and that the ends of fibrillæ, as seen on the section, exist throughout its interior just as on its surface (fig. 38).

2. That fibrillæ taken from any part of a fibre are marked with light and dark points, corresponding in distance and force with the transverse stripes of the fibre.

3. That with a high magnifying power, applied to a thick fibre, we may bring all parts of its interior into focus in succession, and perceive throughout the same kind of stripes.

Fig. 38.



Transverse section of three elementary fibres of the dried pectoral muscle of the Teal (*Querquedula crecca*), treated with weak citric acid; showing the round refracting particles separated from one another. The cut edge of the tubular sheath of each fibre is also seen, as well as the capillary vessel s, *a*, in the intervals.

The occasional *appearance*, therefore, of these stripes being confined to the surface is deceptive. They are sometimes more strongly marked there, partly because there is a greater condensation of the tissue there, and partly from the circumstance of the fibre being usually immersed, when examined, in a fluid of less density than itself. This appearance is always greatly diminished by placing the fibre in syrup. But the point of greatest interest is as to the nature of the markings on the individual fibrillæ or discs. It is unsafe to come to a conclusion on this question from any appearances seen on the entire fibre; for it is clear that the relative position of the particles may be very easily deranged, and their regularity broken, by the slightest injury to the mass.

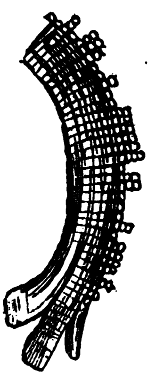
Two *appearances* commonly present themselves in examining the striped fibres: in some parts the cross stripes are perfectly rectilinear, or, if curvilinear, parallel in their course; in other parts, these stripes do not extend across the fibre, but are more or less interrupted, forming zigzags and enclosing spaces of a great variety of shape and size, in concert with the longitudinal stripes. In such specimens we see the semblance of spirals in almost infinite number and variety. The former of these appearances is most seen in large fibres, and where great care has been used not to drag the tissue; the latter under the reverse circumstances. The former seems on a *primâ facie* view an unmutilated, the latter a deranged condition; and they may be proved to be so by a further examination.

For this purpose we should make choice of a fresh fibre which is prone to separate into its individual fibrillæ, and which exhibits their outline in the greatest distinctness and beauty.* If fibrillæ entirely

* The fibres of fishes will generally prove better than those of mammalia, because they usually cleave into fibrillæ having very sharp and clear outlines; and those of the salmon, for example, will seldom fail to do so.

isolated be now inspected, they will be found to present alternate light and dark points, when the part is a little out of focus. The light points are the centres of highly refracting particles, acting as lenses; the dark points, the intervals between them (fig. 37, 8). If now the focus be carefully adjusted, and the achromatic condenser be employed for the purpose of defining the outline with the utmost precision, each dark interspace between the refracting points will be found to be reduced to two very slender straight lines, crossing the fibrilla in a perfectly *transverse* direction, and giving the light spaces, as now seen, a *rectangular* figure (fig. 37, 7). Now, it is absolutely certain that no spiral arrangement could produce, or even co-exist with, these unequivocal appearances; but it is not difficult to comprehend how a derangement of the lateral parallelism of these refracting particles should produce an appearance of spirals in the fibre, or how two fibrillæ running together, but with their particles slightly deranged, should wear the same very deceptive aspect.

Fig. 39.



In fig. 39 is represented the border of some fibres, from which several of the sarcous elements have been removed accidentally by maceration in weak spirit. The remaining ones project in lateral series, evincing their adhesion to one another in that direction, and the non-existence of any spiral arrangement.

The size of the particles composing the fibre may be measured in one direction by the transverse stripes formed by their union.

The following average, deduced from numerous observations, shows great uniformity in this respect.

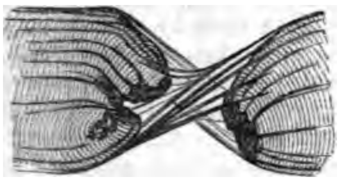
	Eng. In.	No. of Observations.
In the Human subject	$\frac{1}{9400}$	27
" Mammalia generally	$\frac{1}{10000}$	15
" Birds	$\frac{1}{10400}$	7
" Reptiles	$\frac{1}{11500}$	7
" Fish	$\frac{1}{11100}$	20
" Insects	$\frac{1}{9500}$	8

In the opposite direction, or that marked by the distance between the longitudinal dark lines of the fibre, their diameter is less, often by one half. It is important to remark, that these measurements are taken from uncontracted specimens, since during contraction the relative diameters of the particles are changed.

Of the sarcolemma.—The striped fibre is enclosed in a tubular sheath or *sarcolemma*, adapted to its surface, and adhering to it. This consists of a transparent, very delicate, but tough and elastic membrane, which isolates the fibre from all other tissues. In general, it has no appearance of any kind of structure; but in the case of bulky fibres, where it is strong in proportion, faint indications may be detected of a complex interweaving of filaments far too minute to be individually recognized. It occasionally has small corpuscles, the remains of cell-nuclei, in contact with it.

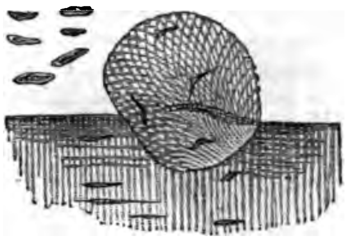
This membrane may be sometimes seen forming a transparent border to the fibre beyond the limit of the cross stripes; or it may be seen stretching between the separated fragments of a fibre which has been broken within it, for its toughness will often resist a force

Fig. 40.



Fragments of an elementary fibre of the Skate, held together by the untorn but twisted sarcolemma.

Fig. 41.

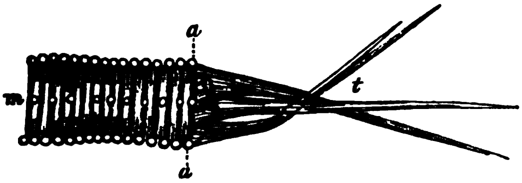


Part of an elementary fibre from the Skate, treated with liq. potassæ; showing a protrusion through the sarcolemma:—Corpuscles are seen scattered throughout the mass, and some detached ones are represented; their average diameter is one-thousandth of an English inch.

before which its brittle contents give way. If the fibre be immersed in acid, it swells, often so suddenly as to burst the sheath at numerous places, and protrude in the form of small herniæ. These herniæ are very peculiar and illustrate the account already given of the internal composition of the fibre; for the particles of the protruded mass are necessarily deranged, and their lateral parallelism destroyed. Now, the result of this is the production of the most beautiful and varied curves, intersecting one another, very similar to those already spoken of on the injured fibre, and wearing a very plausible aspect of spirals (fig. 41). Again, the sarcolemma may be seen raised in the form of vesicles from the surface of the fibre, in certain states of contraction in water, which will be reverted to. By one or more of these modes of demonstration, we know that this isolator of the sarcous tissue invests the striped elementary fibre of voluntary muscle in all animals. Its existence is as yet doubtful in the heart.

Every fibre is attached by its extremities to fibrous tissue, or to some tissue analogous to it; but an accurate examination of this difficult subject lends no countenance to the ordinarily received opinion, that this tissue is prolonged over the whole fibre from end to

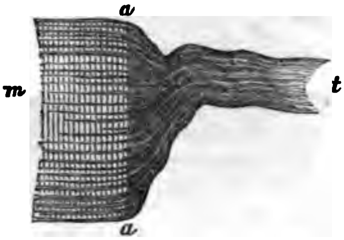
Fig. 42.



Elementary fibre from the leg of the large Meat-fly (*Musca vomitoria*): *a. a.* Line of termination of the fibre, along which the tendon, *t*, is attached to it. *m.* Central series of corpuscles.—Along the margin, the sarcolemma is elevated by water, (which has been absorbed,) and is thereby shown to be adherent to the margin of the discs.

end, as its cellular sheath; nor is this view reconcilable with the physical requirements of the case. It is extremely difficult to isolate a muscular fibre, with the tendinous fibrillæ pertaining to it, either in mammalia or birds; but this may be occasionally accomplished in fishes, and in certain muscles of insects. In these examples, the minute detachment of the fibrous tissue may be seen to pass, and to become attached to the truncated extremity of the fibre. The fibre ends by a perfect disc, and with the whole surface of this disc the tendon is connected and continuous. The sarcolemma ceases abruptly at the circumference of the terminal disc, and here some small part of the tendinous material appears to be joined to it. In other cases, where the muscle is fixed obliquely to a membranous surface, each fibre is obliquely truncated at its extremity, at an angle determined by the inclination of its axis; instances of which may be seen among the crustacea, and elsewhere.

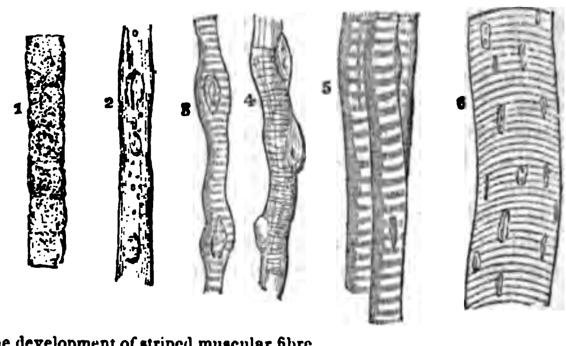
Fig. 43.



Attachment of tendon to an elementary fibre from the Skate:—On bringing deeper and deeper portions of the specimen into focus, along the line of union. *a. a.*, fresh tendinous wavy filaments and striated muscular parts came into view together. *t.* Tendon. *m.* Muscle.

The researches of Valentin and Schwann have shown that a muscle consists, in the earliest stage, of a mass of nucleated cells, which first arrange themselves in a linear series, with more or less regularity, and then unite to constitute the elementary fibres. As this process of the

Fig. 44.



Stages of the development of striped muscular fibre.
1. Arrangement of the primitive cells in a linear series.—After Schwann.
2. The cells united. The nuclei separated, and some broken up; longitudinal lines becoming apparent.—From a fœtal calf three inches long.
3. 4. Transverse stripes apparent. In 3. the nuclei are internal, and bulge the fibre. In 4, they are prominent on the surface.—From a fœtal calf of two months old.
5. Transverse stripes, fully formed and dark; nuclei disappearing from view.—From the human infant at birth.
6. Elementary fibre from the adult, treated with acid; showing the nuclei.—Magnified about 300 diam.

union of the cells is going forward, a deposit of contractile material gradually takes place within them, commencing on the inner surface, and advancing towards the centre, till the whole is solidified. The

ition occurs in granules, which, as they come into view, are to be disposed in the utmost order, according to the two direc- already specified. These granules, or sarcous elements, being e same size as in the perfect muscle, the transverse stripes ing from their opposition are of the same width as in the adult; as they are very few in number, the fibres which they compose f corresponding tenuity. From the very first moment of their tion, these granules are parts of a mass, and not independent of nother; for, as soon as solid matter is deposited in the cells, faint ations of a regular arrangement in granules are usually to be met

It is common for the longitudinal lines to become well-defined e the transverse ones. When both are become strongly marked, always the case at birth, the nuclei of the cells, which were be- isible, disappear from view, being shrouded by the dark shadows d by the multitudinous refractions of the light transmitted through ass of granules: but they can still be shown to exist in the per- bre, in all animals, and at all periods of life, by immersion in a acid: which, while it swells the fibrous material of the granules, bliterates their intervening lines, has no action on the nuclei. ese nuclei in insects are arranged, in the early con- of the fibre, as a single or double series along the fig. 45); and, in the adult state, they retain the position (fig. 42). In vertebrate animals they are red more irregularly, but at pretty equal distances ghout the mass in both fœtal and adult conditions. fully formed fibre, if it be large, they lie at various s within it; but, if small, they are at or near the sur- They are oval and flat, and of so little substance, hough many times larger than the sarcous elements, ing amongst them, they do not interfere with their l apposition and union. These corpuscles are fre- y the cause of irregular longitudinal dark streaks, n the fibre by transmitted light. They usually con- ome central granules or nucleoli. It is doubtful er the identical corpuscles, originally present, remain gh life, or whether successive crops advance and during the progress of growth and nutrition: but it ain, that as development proceeds, fresh corpuscles posited, since their absolute number is far greater in ult than in the fœtus, while their number relatively to the bulk fibre, at these two epochs, remains nearly the same.

Fig. 45.

Elementary fibre from the larva of the Libellula, in an early stage of development; showing the central row of corpuscles.—Magnified 300 diam.

scles grow by an increase, not of the number, but of the bulk ir elementary fibres: there is reason to believe that the number es remains through life as it was in the fœtus, and that the or muscular build of the individual is determined by the mould ich his body was originally cast.

the unstriped fibres.—This variety possesses less interest than her, in consequence of the apparent simplicity of its structure. ibres consist of flattened bands, generally of a pale colour, l at frequent intervals by elongated corpuscles, similar to those

Fig. 46.

Fibres of unstriped muscle:—*c.* In their natural state. *a.* Treated with acetic acid, showing the corpuscles. *b.* Corpuscles, or nuclei, detached, showing their various appearances.

of striped muscle and capable of being displayed by the same process.* The texture of these fibres seems to be homogeneous. By transmitted light, they have usually a soft, very finely mottled aspect, and without a darkly-shaded border. Sometimes the mottling is so decided as to appear granular, and occasionally these granules are arranged in a linear series for some distance. This condition is probably an approach towards the structure of the striped fibre, for these granules are about the size of the sarcous elements already described. It is generally to be seen more or less distinctly in the gizzards of birds; and may be now and then met with in the fresh muscle of the stomach, intestinal canal, urinary bladder, and uterus of mammalia. The ordinary diameter of the unstriped fibre is from $\frac{1}{3000}$ to $\frac{1}{2000}$ of an inch.

It might be expected, from this account of the appearance of these fibres, that their discrimination from other tissues would be often difficult. The peculiar texture, however, the size, the soft margin, and, above all, the presence of numerous elongated oval corpuscles with two or three granules near their centre, are characters which, when united, will seldom be mistaken. As a number of fibres commonly take a parallel course together, the bulgings occasioned by the corpuscles give rise to partial longitudinal shadows, extending for some way beyond the corpuscles in the intervals of the fibres. As these irregular longitudinal shadows occur pretty uniformly throughout a bundle of fibres, and as some of them are necessarily out of focus, while others are in focus, the whole mass commonly presents a confused reticulated appearance, which has given rise to an almost universal notion that the fibres interlace one with another. This idea, however, is, in most cases erroneous. It is doubtful whether these fibres are invested by a sarcolemma: none has hitherto been detected in an unequivocal manner. It is also still a matter of speculation how they terminate, or whether they in all instances have a termination. In the case of the transverse fibres of the intestine, for example, it is uncertain whether each fibre surrounds the canal once, returning into itself as a ring, or more than once, as a spiral; or whether it passes only partially round it, the circle being completed by others. Whether the areolar tissue (the representative of the fibrous), that is found in connection with these fibres, serves to give them an attachment, by union with their extremities, or by involving them in its meshes, is also altogether unknown.

* In some specimens, however, of both varieties of fibre, they may be discerned without the addition of an acid.

the gizzard of the bird, the ends of the fibres are united to white rous tissue, thus making an approximation to the striped fibre, as ey do in colour. But we have not been able, after diligent search, detect the true transverse stripes, which Ficinus describes to exist this organ.

Of the distribution of the two varieties of fibre in the body.—The iped fibre is met with in all muscles of the body whose action can directly influenced by the will, and also in those of the pharynx, e œsophagus, and the heart. In the œsophagus it seems to be min-ed with the other variety to a somewhat uncertain extent. In some ecimens from the human subject we have failed in detecting any the lower half of that tube, either in the circular or longitudinal yer; but in another example we have found them to within an inch the stomach.* It is still unknown in what manner the two kinds fibre are arranged at their point of junction: some supposing them be intermingled; others, that they pass into one another by imper-ptible gradations of structure. The former of these views is the more cordant with our own observations; and Mr. Mayo mentions a fact, hich seems to corroborate it: "When the nervi vagi are pinched, one dden action of the fibres of the œsophagus ensues, and, presently ter, a second, of a slower character, may be observed to take place." *'hysiology*, 3d ed. p. 41.) The characters of these movements ould appear to indicate the existence of both varieties of fibre.

The cross stripes on the fibres of the heart are not usually so gular, or distinct, as in those of the voluntary muscles. They are en interrupted, or even not visible at all. In some of the lower imals their sarcous elements never form transverse stripes. These res are usually smaller than the average diameter of those of the luntary muscles of the same subject by two-thirds, as stated by r. Skey; and in most parts of the parietes of this viscus they are t aggregated in parallel sets, but twine and change their relative sition. This may be seen in a well-boiled heart. Striped fibres ve been found in the iris, in the small muscles of the ear, and in ose muscular fasciculi that surround the urethra immediately in nt of the prostate. They are also found in the sphincters of the us and vagina.

The unstriped fibre is met with in the alimentary canal, and con-tutes the double layer investing that tube. It also forms the mus-lar coat of the bladder, and that of the uterus. The dartos owes contractility to the presence of fibres of this variety; which, in nsequence of their admixture with a great abundance of areolar sue, have been often overlooked. But they may be detected by e addition of acetic acid, which, by bringing into view the peculiar rpuscles they contain, distinguishes them from both the white and llow fibrous elements of the areolar tissue. A very distinct peri-ltic contraction may be often discerned in the dartos, extending ross the raphé of the scrotum, and too similar to the contraction of striped muscle to be mistaken.

* Among the lower animals, Mr. Gulliver has pointed out similar varieties. (Pro-d. of Zool. Soc., No. 81.) (See also Lancet, Aug. 1842.)

The fibres which have been described as peculiar to the dartos seem to be nothing more than a certain modification of the areolar tissue in that region. The erection of the penis may be, in part, owing to the compression exerted on the superficial veins of the organ by a continuation of a structure analogous to the dartos, which is continued over the base of the penis under the skin. The erection of the nipple also occurs, on any mechanical irritation, with a motion so very like muscular contraction, that a layer of these might perhaps be found under the skin of that region. And it may be matter of question how far the general contractility of the skin may be dependent on a diffusion of this tissue, in small quantities, throughout its areolar structure. The excretory ducts of all the larger glands seem to possess a covering of fibres pertaining to this variety: such is the case with the ductus choledochus in birds, and probably in mammalia, and with the ureters and vasa deferentia. The bronchial tubes may be here alluded to in their capacity of an excretory apparatus, as furnishing the best marked example of this arrangement. The trachealis muscle consists evidently of the unstriped fibres, and the same may be traced down the bronchial ramifications as far as the air-cells themselves, though not into them. The distinctive characters of this form of muscle may here be unequivocally discerned; and, if anatomists had been better acquainted with them, there would not have been room for those disputes regarding the muscularity of the bronchial tubes which have so long attracted the interest of practical physicians. Recently, indeed, there has been added to the satisfactory evidence of anatomy the fact, that these fibres may be excited to contraction by the galvanic stimulus. (*Dr. C. J. Williams, on Diseases of the Chest.* Last edit. Appendix.) In the case of other glands, it is still unknown how far the muscular coat invests the ramifications of the duct: it is most likely that it gradually ceases a short way within the organ, and at least it seems clear that no portion of the secreting membrane itself is ever invested by it.

Distribution of the two kinds of fibre in the animal scale.

The striped fibres have been found in all vertebrated animals, and in insects, crustacea, cirropods, and arachnida: and future researches will probably show them to be even more extensively diffused. But in the lower animals we find that the distinctive characters of the two varieties begin to merge together and be lost; especially where the fibres are of diminutive size. The transverse stripes grow irregular, not parallel, interrupted; a fibre will, perhaps, possess them only near its centre, where its development is most advanced, and its contractile energy greatest. Even the peculiarities of the unstriped fibre are sometimes no longer to be met with in parts which are undoubtedly muscular, as the alimentary canal of small insects. It is evident that fibres of the usual bulk would be greatly too large for the requirements of the case; and they consequently seem to be reduced within limits which deprive them of those anatomical characters by which alone we can elsewhere positively aver their existence. It is possible that a tissue identical in nature and properties with that of striped muscle, may be the effective agent to which are due those wonderfully vivacious movements witnessed in the bodies of many of the minutest infusoria, where the best microscope can hardly discern even the organs put in motion.

Each one of the elementary fibres now described may be properly regarded as a distinct and perfect organ. In some of the smaller forms of animal life, we have examples of a striped muscle consisting of a *single fibre;* and not only so, but this fibre reduced to a single series of sarcous elements, or a *fibrilla.* But in all the larger animals, and in the human body, with which we are specially concerned, solitary fibres never occur: they are always aggregated in parallel series of greater or smaller size, and associated with other tissues, which minister to their nutrition, or to their mechanical connection either to one another or to neighbouring parts. Thus the compound organs termed *muscles* are formed.

In these, the angular figure of the fibres results from their contact. The sets in which they are packed usually contain ten, twenty, thirty, or more; these again being united into larger sets, and so on, so as to form the variously sized *fasciculi* and *lacerti* of Prochaska and others, until the whole muscle is formed, consisting, it may be, of very many thousands. Though the fibres of a small set are always parallel, and the primary sets usually so, it often happens that the larger sets are placed obliquely to one another, and therefore do not act in the same direction; and, even when all are parallel to one another, they are often oblique to the cord or tendon their force acts upon. Such muscles are styled doubly or singly *penniform*, from their resemblance to the plume on a writing-quill. All such arrangements, infinitely varied, are mechanical contrivances by which symmetry of form, or extent of motion, is obtained at the expense of power.

White fibrous tissue reaching from the end of a muscular fibre to some structure which is to serve as a fixed attachment for it, or which it is intended to move, is called a *tendon.* The fibrous tissue thus running from many contiguous fibres (as those of a whole muscle) is usually united into a single tendon. This may be lamellated, cordiform, &c., according to the arrangement of the muscular fibres themselves (see p. 81).

Tendinous fibres are much less bulky than the muscular fibres of which they are the prolongation; and from this result many consequences. Tendons are employed for symmetry, and where muscular structure would be useless, from the mechanical impossibility of more than a certain amount of motion in a part. Moreover, where a muscle consisting of a large number of fibres has to be attached to a large surface, the tendinous fibres are diffused; but, if the same muscular substance has to be fixed to a small point of bone, the tendon must be collected into a cord. Now, it would be impossible for all these muscular fibres to be attached to the tendinous ones on the same level, on account of the great difference in bulk between the two structures. Hence, in such cases, we find the muscular fibres to end in tendon in regular progression one after the other, and the tendon at its muscular extremity to be expanded, some of its fibres being long, others short. And yet the inconvenience which would ensue from the muscular fibres being of unequal length in the same organ, is counteracted by the tendon at their other extremity having its fibres precisely reversed; as in the rectus of the thigh, and numerous other

instances. Where muscular fibres are really of different lengths in a muscle, it is because, from the direction in which they act, they have to shorten to different degrees. Thus, in the square pronator of the fore-arm, the deeper and shorter fibres are attached to a part of the radius, which in pronation passes through a much smaller space than that to which the superficial and longer fibres are fixed: and under the innumerable modifications of muscular form in man and animals, however force is sacrificed to mechanical exigencies, or other causes, it is invariably accomplished with the utmost economy of power consistently with the end in view; there is never any waste, never any force provided which is not wanted.

Where a great mass of fibrous tissue runs into a muscle, the number and obliquity of the muscular fibres are very much increased, while the length of each is diminished; and, as a general result, the power of such a muscle is great, the extent of its contractions comparatively limited.

A given mass of contractile material may be arranged as a few long fibres (as in the sartorius), or as many short ones (as in the masseter): its contractions would, in the former case, be characterized by their extent; in the latter, by their power: for, *cæteris paribus*, the extent is as the length, the power as the thickness.

The terms *origin* and *insertion* are employed with great convenience in ordinary language to denote the more fixed and the more movable attachments of muscles. In human anatomy general consent has sanctioned their use, and even with few exceptions their particular application to each muscle in the body; although this assignment is in many cases arbitrary, in consequence of its being impossible to determine which attachment is the more frequently the fixed one.

The arrangement of the fibres in the *heart* is very peculiar. Without attempting a particular account of their course, we may state that they do not preserve the same parallelism, nor extend straight between two points, as in the voluntary muscles, but twine round one another, and around the organ, in a very intricate and more or less spiral figure. Most of them come from the tendinous cord encircling the orifices of the ventricles, and, after winding through their walls, return either to some part of the same circle of tendon, or end as one sort of columnæ carneæ in the ventricles by union with the chordæ tendineæ.

In the muscular coat of the alimentary canal, of the bladder and uterus, the unstriped fibres are disposed, as in the heart, so as to enclose a cavity, but without having, as in that organ, any point at which they can be said to commence or terminate. In the alimentary tube they are arranged in two laminæ, the respective fibres of which take a course at right angles to each other. In the bladder the arrangement is reticulate. The elementary fibres form sets of variable thickness, which at numerous points send off detachments to join neighbouring bundles, whence has sprung the notion that the fibres are branched. It is manifestly, however, the sets of them only that are branched; the unstriped, like the striped fibres, being invariably simple from end to end. In the uterus the disposition of the fibres is

essentially similar, calculated to allow of great variety in the capacity of the cavity they encircle.

Of the areolar tissue of muscles.—This tissue is much more abundant in the voluntary than in the involuntary muscles. To the former it gives an external investment, which sends septa into the intervals between the larger and smaller packets of fibres, and thus enables them to move in some degree independently of one another. The density of these general and partial sheaths is proportioned to the amount of pressure to which the organ may be subject, as is exemplified in the superficial muscles of the back, and in those superficial muscles generally where a fibrous aponeurosis does not exist. The areolar tissue does not usually clothe every individual fibre from end to end, giving it a cellular sheath, except in cases where the elementary fibres are of large dimensions. The areolar tissue, besides affording protection to the muscular fibres, admits of motions between them; and, by forming a connecting bond between neighbouring bundles, it must also serve the important office of limiting undue motions of one part of a muscle on another part. But a principal use of it appears to be that of furnishing a resisting nidus in which the delicate vessels and nerves can traverse the interstices of the fibres, and by which they can be protected from hurtful dragging during the unequal and oscillating movements of the fibres of a voluntary muscle in its state of activity. This idea is supported by the fact that scarcely any areolar tissue exists in the heart, or in the unstriped muscles generally. In the heart, though the contraction is powerful, it is instantaneous, or nearly so, and therefore probably more uniformly diffused, so that neighbouring fibres must be less moved on one another than in the more sustained contraction of a voluntary muscle. Moreover, the mutual intertwining of even the elementary fibres in this organ is in many parts of it so intricate, as to contribute much to their mutual support; and, in the other involuntary muscles, the contractions are slowly and evenly progressive along the fibres of the same set.

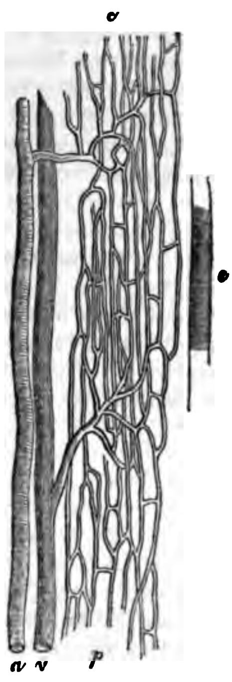
Of the blood-vessels of muscles.—The arteries and veins of muscles commonly run together; and most of the arterial branches, to within two removes from the capillaries, are accompanied by two *venæ comites*. They invariably pass more or less across the direction of the fibres, divide and subdivide, first in the intervals between the larger sets, then between the smaller sets, till the ultimate twigs insinuate themselves between the fibres composing the smallest bundles, and break up into their capillary terminations. In this course the vessels supply the areolar tissue, their own coats, and the attendant nerves. The capillary plexus of the areolar membrane consists of irregular but pretty equal-sized meshes, and contrasts strongly with that of the muscular tissue itself.

The *proper capillaries* of muscle are quite characteristic in their arrangement, so that a person, who has once seen them, can never afterwards mistake them. They consist of longitudinal and transverse vessels: the longitudinal always following the course of the elementary fibres, and lying in the intervals between them; the transverse

being short communications placed at nearly equal distances between the longitudinal ones, and crossing nearly, or quite, transversely over or under the fibres. The manner in which the longitudinal vessels are placed in relation to the fibres, is seen in fig. 36, represented as they are seen on a transverse section. They usually occupy the interstice between three or more fibres, but sometimes also the space between the contiguous surfaces of two fibres. The length of the longitudinal vessels does not usually exceed the twentieth of an inch; in other words, the terminal twigs of the artery and vein pertaining to the same capillary are seldom further than that apart. The length of the transverse anastomosing capillaries necessarily varies with the thickness of the fibres over which they pass (fig. 36, B, *a*).

The diameter of the capillaries of muscle varies, like that of others, with the size of the blood-particles of the animal. It is, however, only just sufficient to allow of the particles to pass. If a fragment of a frog's muscle, perfectly fresh, be examined, series of blood-particles will be seen in the longitudinal capillaries. These particles are compressed and elongated, sometimes to a great extent, evidently by the narrowness of the canal which contains them. It may seem at first sight not doubtful that in the living creature these elastic blood-discs are similarly elongated in their passage through the vessels of muscle, but the admirable researches of Poiseuille will perhaps serve to explain this appearance without our being driven to suppose the presence of so formidablean obstacle to the capillary circulation through these organs. It is more probable that the contraction of the vessels, and the compression of the blood-discs, occur on the escape of some of their contents being permitted by the cutting off of the fragment for microscopic examination. The coats of the capillaries of muscle consist of a simple diaphanous membrane, in which a few irregular-shaped cytoblasts occur at infrequent intervals.

Fig. 47.



Capillaries of a small fasciculus of muscular fibres from the neck of the Dog:—*a*. Terminal twig of the artery. *v*. Terminal twig of the vein. *p*. Plexus of capillaries *e*. Elementary fibre, to show the relative size and direction of those to which the capillaries, here represented, are distributed.

It results from this description of the capillaries of muscle, that their number must correspond nearly to that of the elementary fibres; consequently, that the same amount of muscular tissue, arranged as a large number of small fibres, would be supplied with a larger absolute number of capillaries than if arranged as a small number of large fibres. This difference of vascular supply is exceedingly remarkable, and will be reverted to in considering the contractility of muscle.

Of the nerves of muscle.—Nerves being the appropriate channel

h which muscles are excited to contraction, we have now to : into the manner in which the two tissues communicate :r. As far as is at present known, all muscles in the larger s have nerves distributed to them; and, if we extend the in- ɔ those extremely simple and minute muscles which have been r alluded to as existing in the smallest of living creatures, we can no longer trace nerves, yet our inability to do so pro- lepends more on a corresponding simplicity of the nervous sub- itself, so that it ceases to be anatomically recognizable, than :ntire absence. So general is the connection of the two tissues, apparently indispensable for the subjection of the muscles to poses of the organism of which they constitute a part, that we gard it as constant and necessary.

distribution of the nerves through muscular structures has been a subject of great interest to those who looked to this inquiry for some clue to the explanation, either of that won- active connection subsisting between them, or of the nature of ntractile act itself. But though the anatomical results accruing is inquiry are of a highly satisfactory kind, considered in them- alone, yet they cannot be said to have hitherto contributed in :at degree to the elucidation of these mysterious questions. :st mode of inspecting the arrangement of the ultimate nervous s, to select a very thin muscle, as one of the abdominal mus- any small animal, or one of the muscles of the eye of a small steep it in weak acetic acid, en to thin it out under the ssorium. The primitive tu- of the nerve may then be distinguished with a mode- iigh power. They separate ne another at first in sets, rds in twos, threes, or fours; these be followed, they will id ultimately separating from other, forming arches, and ng either to the same bundle hich they set out, or to some ouring one (fig. 48).

Fig. 48.

Loop-like termination of the nerves in voluntary muscle.—After Burdach.

is loop-like course they ac- iy to some extent the minute vessels, but do not accurately them in their last windings, ieir distribution is in a differ- ire. They pass among the f the muscle, and touch the mma as they pass; but, as far ent researches have informed y are entirely precluded by ucture from all contact with the contractile material, and from aediate intercourse with it. How then shall we explain the

transmission of the nervous influence to a material thus enclosed? If it were wise or safe to go a single step in advance of pure observation on so abstruse a question, we might suggest, resting on the seemingly sure ground of exact anatomy, that this influence must be of a nature capable of emanating beyond the limits of the organ which furnishes it. But further than this, as to how, or to what extent this influence may so emanate, or as to what may be its nature, it would, perhaps, in the present state of knowledge, be hardly warrantable even to speculate.

The number of fibres in a muscle is always exactly proportioned to the power demanded, and their length to the amount of shortening required of them; but, these circumstances being secured, muscular parts are subject to great variety of form, being short, thick, or rounded, long, slender, or flat, according to their position relatively to particular bones, joints, other muscles, or the like. Thus, all are compactly knit and adapted to work in concert, without any mechanical interference with one another; and perfect symmetry, both of shape and action, is provided for.

We notice that the muscles are arranged on the skeleton in a great measure in sets, having opposite actions; as, for example, the flexors and extensors, pronators and supinators of the fore-arm. It is evident that the action of every muscle depends solely on its mechanical attachments, and that a tendon running round to a different side of a limb might quite reverse a given action. But we find that in general the muscles of the same set are designed to act together, not only by their attachment on the same side of a joint, but by a supply of nerves from the same source (congeneres). Yet even this can confer no special action of extension or flexion, but only an association of action which may be both at once; for example, the flexors of the toes extend the ankle, and the extensors of the toes bend it. Even a single muscle, the rectus femoris, flexes the thigh, and by the same action extends the leg. Muscles opposed in action are termed *antagonists*. This antagonism is in most cases required by the necessity there is for an active moving power in opposite directions; but it serves the important accessory purpose of elongating muscles when they cease to be contracted, as we see illustrated by the presence of elastic or some other force for the same purpose, when there is no antagonist muscle. When antagonists act together, the part is fixed.

The locomotive framework may be regarded as a series of levers, of which the fulcrum is for the most part in a joint, *i. e.* at one extremity, the resistance at the further end, and the power (or the muscle) in the intermediate portion. In most cases the muscles are attached very near the fulcrum, as in the familiar instance of the biceps, inserted into the tubercle of the radius. By this disposition, a contraction of a single inch in the muscle moves the hand in the same time through the extent of a foot, but then the hand moves through every inch with only the twelfth part of the power exerted in the muscle; *i. e.* a resistance at the hand equal to one-twelfth of the force of the muscle would stop its motion. Thus, force is converted into extent and velocity of movement, at the same time that the great

inconvenience is avoided of having the muscles extended like bow-strings between the distant ends of jointed continuous levers. By the junction of two or more levers in one direction, as in the different segments of the extremities, the extent and velocity of their united actions are given to the extreme one. A blow of the fist may be made to include the force of all the muscles engaged in extending the shoulder, elbow, and wrist.

In the conspicuous example of the tendo-Achillis, inserted into the os calcis, the resistance (or the weight of the body) rests on the astragalus, intermediate between the power and the fulcrum, which is here the ground, pressed by the ball of the foot. The extent and velocity of motion are here converted into power. If the tendo Achillis draws on the heel when the foot is off the ground, the front part of the foot is extended on the lower end of the tibia as a fulcrum, and exhibits an instance of the other of the three varieties of lever.

Of the function of muscles.—The great property of muscular tissue is that of shortening in a particular direction, and this property is called *contractility.* It is not that mechanical power which elastic substances possess of shortening themselves on the removal of some force which has stretched them, but it is an endowment, responsive to appropriate stimuli, and diminishing or disappearing with the healthy state of the tissue (p. 69–70).

The distinction between the contractility, the elasticity, and the physical tenacity of a muscle may be illustrated by the following imaginary experiment: Suppose the leg of an animal so severed from the trunk as to hang by a single muscle, which, after retaining its contractility for some time, were gradually to lose it. The limb would at first be borne up by the contractile power: but, as that ceased, the muscle would elongate under the weight, and the limb would remain suspended simply by the tenacity of the part. If, now, the muscle were stretched between the hands, we should find it to possess some slight elasticity. The elasticity and much of the tenacity of muscles are attributable to the sarcolemma, and to the capillary and areolar tissues. It does not appear that elasticity is in any degree a property of the sarcous elements, and their tenacity must be comparatively slight: but it is the sarcous tissue alone that possesses contractility.

Although it is universally allowed that the muscular tissue is the contractile substance, yet the strange question has been raised, and is still warmly debated, whether it possesses this power in itself, and independently of all other tissues: some contending that nerve is necessary to confer contractility on muscle,—to charge it, as it were, with this property; others, that nerve is only necessary to call it into action; and others, that the property is the essential attribute of the tissue, and totally independent of all nerves. The time is past when the intricacies of this keen contest can be threaded with any benefit to the student, and we therefore refrain from attempting to follow them. We shall prefer offering him a view of the facts of the subject, as at present known, drawing our conclusions as they arise.

The contractility of muscle is exhibited in two varieties of contraction, passive and active.

Passive contraction is that which every muscle is continually prone to undergo, by the mere quality of its tissue, as long as it remains in its natural situation in the body. The muscles are ever kept on the stretch by the nature of their position and attachments, and cannot have their ends so approximated, by attitude or otherwise, that their tendency to shorten themselves shall cease. If, for example, the rectus muscle of the thigh have its extremities brought as near together as can be effected artificially by posture, they would yet be found to approach still nearer on being freed from their attachment to the bones. The stimulus to this contraction may be therefore considered to be that of extension. In fractures and dislocations attended with shortening of the limb, the muscles adapt themselves permanently to their shortened state by virtue of this property. This tendency to contract has been distinguished by the term *retractility*, from its being manifested by the retraction that occurs when the belly of a muscle is cut across. But, in this instance, the retraction would appear to be in part caused by an active contraction excited by the stimulus of the injury. It has been also styled *tonicity*. It is well exemplified in all those contracted states of muscles which follow paralysis of their antagonists, as when the features are drawn towards the healthy side in hemiplegia. The passive contraction of muscles is continually opposed to their elongation by the active or passive contraction of antagonists, and restores them when that subsides. By it they are accommodated to an attitude artificially given, when no muscular effort is required to maintain it. When no active contraction is present in a limb, the passive contraction remains; and being brought to a state of equilibrium in all the muscles, by their mutual antagonism, the limb is said to be at rest. This is the general condition during sleep, in which the posture assumed by the limbs is determined by the relative power of antagonist muscles: the flexors overcome the extensors, and hence the limbs are bent.

Active contraction is attended with those striking manifestations of power that specially characterize muscle. It is always excited by a local or partial stimulus, and is always exerted in opposition to another force within the body, which it is able more or less completely to master. The opposing force is generally the passive contraction of antagonist muscles, as well as the weight or resistance of some part upon which the muscle acts directly; but it may be the elasticity of parts, or, in the case of hollow muscles, the resistance of their own contents. Active contractions are also frequently opposed to one another in the maintenance of a fixed posture. Active contraction is partial and interrupted, both in extent and duration. It requires intervals of rest, being attended with exhaustion of the power which produces it; which exhaustion, in the voluntary muscles, is attended with the sensation called *muscular fatigue*.

The contractility of muscles, therefore, is being ever exerted, in obedience to the equable stimulus of tension, without fatigue, in the production of what we have termed passive contraction; when it is

affected by a powerful, partially-applied stimulus, active contraction results, inducing the necessity for subsequent rest. But there seems no good ground for supposing the contractile force to differ in its nature, when exhibited under these different modes of action.

Stimuli to muscular contraction.—Whatever is capable of inducing contraction in the muscles, when either naturally or unnaturally applied to them, is termed a stimulus. In the living body, the muscular fibres are in most instances made to contract by the immediate influence of the nervous tubules distributed among them; and this influence, however called into play, should be styled the nervous stimulus, or the *vis nervosa*. This nervous stimulus, then, is simply the effect of such a condition of the motor nerves as enables them to induce contraction in muscular fibres which are in the due relation to their terminal loops. Of the nature of this condition, and of the mode of its production, we are as completely ignorant as we are of the nature of all those other conditions of the nervous system on which the manifestation of its various phenomena depends; but we know some little of the agents by which the nerves are thrown into this state. The chief of them are volition, emotion and impressions carried by the afferent nerves to the nervous centres, and there affecting the efferent, or motor nerves, independently of volition or consciousness; but to these are to be added various impressions from diseases and injuries of the motor nerves, either at their origin or in their course, together with pressure, heat, chemical substances, electricity, &c., applied to their texture. The former are the natural excitants of the nervous stimulus in the living body; the latter may be proved to possess this property by observation, and by experiments on nerves distributed to muscles, either in the body, or soon after their removal from it. The power of inducing contraction in the muscles is an endowment of those nerves only which have a certain organic connection with the muscles; and these nerves are, therefore, distinguished as *motor*.

There are other stimuli of muscle besides the vis nervosa, which occasion contraction in the living body; but, in general, these affect only the hollow muscles. Experiment has, indeed, shown these muscles to be under the influence of motor nerves derived from the spinal marrow; but it seems probable that some of them, at least, are normally excited to contract by the stimulus of stretching or distension, to which they are peculiarly liable from their arrangement as investments to hollow viscera. Muscles have not the capacity of elongating themselves that has sometimes been ascribed to them: when once contracted, they remain shortened, notwithstanding the contractile force have subsided, unless their ends be drawn apart by some extraneous force. This force is that which has been already specified as being always exerted in opposition to active contraction in the living body. In the case of the voluntary muscles, this force always continues to act after the active contraction has ceased; but in the case of the hollow muscles, where it consists of the resistance of their contents, it sometimes happens that these, when removed, are not at once replaced; and hence an enduring contraction, though the active contractile force is no longer exerted. Thus an empty intestine is

reduced to the size of a tobacco-pipe, and the sphincters of the anus and bladder are kept contracted, without any tetanic spasm, or permanent expenditure of contractile force, as has been sometimes supposed.

Now, the stimulus of distension is, in the first instance, nothing more than the elongating force which calls into play the contractility of a muscle under its passive form: and there is this peculiar to it, that it affects equally every point of the substance of each fibre, which no other stimulus can do: and hence would result the uniformity which will presently be shown to characterize passive contraction, for contraction is an answer to a stimulus. This consideration tends strongly to confirm the view which we have taken of the identity of the forces displayed in passive and active contraction, of *tonicity* and *contractility*.

Other stimuli may be mentioned as capable of causing muscular contraction by their direct agency on the tissue; but it is important to observe that these take no share in the production of natural contraction in the healthy body. It was long supposed impossible to observe the effect of stimuli on the muscular tissue when isolated from the nervous; and the fact, that the artificial stimuli which induced contraction when applied to a muscle itself, were the same with those which induced it when applied to the motor nerves, was considered sufficient proof that in the former case the effect was produced through the medium of nervous tissue still mingled with the muscular.

But this question has been brought to an issue by the positive observation that fragments of the fibre of voluntary muscle, entirely isolated from every extraneous tissue, whether nerve or vessel, may be made to contract in obedience to a stimulus topically applied to them. When such fragments are examined, they are found to contract first of all where they have sustained mechanical injury, viz. at their broken extremities; and, if water be brought into contact with them, it is absorbed, and thereby excites them to contractions, which commence at their surface.* The same thing is frequently to be observed under a different form. A particle of foreign matter, as a hair or a piece of dust, may be included by design or accident in the field of the microscope, so as to touch the side of a fibre at a single point. When this happens, the fibre will often exhibit a contraction, so plainly limited to the point touched, as to give unequivocal proof of its being the result of the irritation of the pressure. Chemical substances may be seen to act similarly, if they be not so powerful as to destroy the texture of the part: and it is probable that electricity has a like agency. These interesting phenomena may be

* Water has long been known as a rapid exhauster of the contractility of muscles. "Rigidity is produced almost instantaneously if warm water be injected into the arteries of a muscle. The flesh, under these circumstances, becomes pale, increased in bulk, and suddenly hardens. The operation of crimping fish consists in dividing the muscular fibre before it has become rigid, and immersing it in spring water. A small part treated in this manner contracts and hardens within five minutes."—Mayo, Physiol., p. 38. It exhausts contractility by inducing violent contraction, by which the fibre is often disorganized.

bserved more or less satisfactorily in all animals whose fibres retain ıeir contractility for a sufficient length of time after removal from the ody; and the crab and lobster will be found very favourably adapted ır the purpose. In many reptiles, and fish also, the steps occur owly enough to be adequately scrutinized.

The facts in question can admit only of one explanation, if it be onceded that the muscular tissue has been here separated from the ervous: and certainly that separation has been effected, unless the ervous tubules send off from their terminal loops a set of fibrils hich penetrate the sarcolemma, and diffuse themselves through the ontractile material within; a supposition for which there exists, at resent, no foundation in the observations of the most diligent investi- ators of this subject. They will, therefore, probably, be regarded s conclusive proof that contractility is a property inherent in the very tructure of muscle, and capable of being excited to action independ- ntly of the instrumentality of nerves.

An interesting phenomenon has been pointed out by Dr. Stokes, hich, when illustrated by the foregoing observations, we may safely onsider as an example of contraction in the living body in answer to physical stimulus. In various cases of phthisis, and, indeed, in ll cases attended with emaciation, a sharp tap with the fingers on ny muscular part is instantly followed by a contraction, and by he rise of a defined firm swelling, at the point struck, enduring everal seconds before it gradually subsides. This is often so pro- ainent as to throw a shadow along the skin, and for the moment it ıight almost be mistaken for a solid tumour. That it is limited to ıe point struck is full proof of its being a direct effect of the irrita- on, and not produced through the medium of nerves; for a contrac- on excited in the latter mode would be diffused over the parts to hich the nervous twigs irritated were supplied, and would therefore equently occur in parts at some distance.

Having premised these words respecting the stimuli of muscle, we roceed to consider what is known of the phenomena which attend ıe act of contraction. It is evident that the subject we are now pproaching is one of primary importance, because on the positive ıformation regarding it must chiefly depend our means of judging of ıe conflicting hypotheses of the nature and laws of action of the con- actile force.

A muscle, when contracted, is firmer than before; but this rigidity proportioned rather to the intensity of the contractile force exerted, ıan to the amount of shortening occasioned by it. The circumstance, owever, has led to the belief, that the act is accompanied with a ompression of the substance of the muscle into a smaller compass; ut it is, on the contrary, well ascertained that it gains in thickness hat it has lost in length. The experiments by which this fact is tested have been often repeated, and their general results accord ell together. If a muscular mass be made to contract by means of alvanism in a vessel of water furnished with a very delicate tube, ıe slightest diminution of bulk would be at once indicated by the ll of the water within the tube; but the water, under these circum-

stances, is found to retain its level. Mr. Mayo varied this experiment by selecting the heart of a dog, (*Anat. and Phys. Comment.* vol. i. p. 12,) which, continuing to beat during some time, was in this way distinctly seen to undergo no change of size.

The familiar practice of accelerating the flow from the vein at the elbow by desiring the patient to contract the muscles of the fore-arm, does not, as is sometimes imagined, show any diminution of their bulk, but only a forcible increase of their lateral dimensions, by which the deep veins are compressed within the inelastic sheath of fascia, and the blood diverted into the superficial channels. In those muscles which have a bulging centre or *belly*, as the biceps of the arm, the fibres are arranged in a curved form, and during contraction must tend towards a straight line in the direction of the axis of the muscle. In such instances the blood-vessels that traverse their interstices must be in some degree compressed.

If we examine under the microscope the contracted state of a morsel of the sarcous tissue, we find it to present essentially the same characters as that of the entire organ, a shortening in length, with a corresponding increase in thickness ; and this is true, however minute the fragment may happen to be. This is all that can be said in general of the visible features of this remarkable phenomenon. Late investigations, instead of explaining the manner in which contraction is effected, by showing its dependence on forces previously understood, have only served to display the inadequacy of the coarse and mechanical hypothesis, that physiologists have been so prone to confide in, and to make it more than probable that they must ever be content to repose upon the fact above stated, as the simplest which the most refined microscopical analysis will ever disclose.

All muscle retains its contractility for a longer or shorter period after its separation from the body, or after death. During this period contractions may be excited by the nervous, and all other stimuli, which we can apply to it; and it is certain that these contractions are the same in their nature with those occurring in the living body under natural influences. Being also easy of inspection, they are admirably suited to the display of the minute changes occurring in muscle during its active state.

The muscle with striped fibres is peculiarly adapted for the display of these changes ; for, its texture not being homogeneous, but marked throughout with perfect regularity into spaces or particles so minute as to require to be very highly magnified before they can be even seen at all, the anatomist is provided with the means of detecting movements, which, without this circumstance, must have remained concealed.

When a piece, retaining its contractility, is torn up into its elementary fibres, the fragments of these, when placed in water, are seen to undergo a slow movement at certain points, especially where they have suffered violence, as at their broken extremities. This movement consists of a shortening and thickening of the material composing the fibre, as is shown by the general outline of the part, but especially by the appearances visible in its interior. The transverse

both light and dark, become longer and thinner: in other he discs expand in circumference, flatten, and approximate another; or, to use another form of expression, the fibrillæ shorter and thicker, both in the particles composing them and rial connecting those particles (fig. 49).

changes are always local, or partial; and it is most evident, characters they constantly present, that they are not limited eterminate regions, points, or segments, but occur indifferently r the exciting cause may chance to be exerted. Neither discs llæ appear to have the smallest share, as aggregations of paraing those particular forms, in producing the phenomena of ion. A contraction is never bounded to a particular number or fibrillæ, and is never accurately limited by the interval two discs. It constantly happens, that at the edge of the ed part, several discs are only partially engaged in it. A ion generally, when commencing at the broken end of a fibre, its whole width there; but, when it commences at the border re, it may be confined to a portion of many discs: and, fur- contractile force is never exerted along the whole length e or fibrilla at once. A contraction excited in an elementary the contact of a hair extends into the mass equally in all s, as we might suppose it would do, if the mass were homo-

tentive study of these interesting phenomena will lead to the on, that, in the bare fact of contraction, the *build* of the fibre m of no importance whatever: the exquisite symmetry disn the apposition of its component particles is, as it were, disl and overlooked; while the whole process is to be referred aterial itself, the ultimate tissue, whose property is *contract-* his property appears to reside both in the particles and the e connecting them.

ltimate movements, therefore, on which contraction depends, r they may consist in, are molecular, and far beyond the reach

l be perceived that this view of the subject is the only one n harmonize the fact of contraction in voluntary muscle with phenomenon in structures which have no complicated internal ent of particles, as, for example, in the unstriped fibre; and actility manifested by fibrine, immediately after coagulation, erty too nearly allied to the contractility of muscle (a form of ot to give it additional credibility.

garding contractility, therefore, as a property of the living r fibre *in general,* it is meant that it resides in it as a property which it would not be muscle; and in such a manner, that no however microscopic, can be detached from muscle which of itself, and independently of the rest, possess this property s it possesses vitality.

Of the differences between the minute movements of Muscle in passive and active contraction.

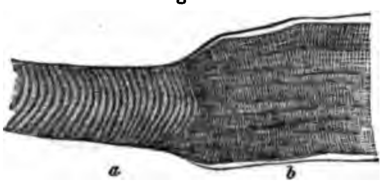
In *passive contraction.*—It is perhaps impossible in the higher animals to observe the nature of the microscopic movements occurring in muscle in its ordinary state or during its passive shortening; but, in the lower and smaller forms of life, this may sometimes be accomplished. It may always appear doubtful, however, whether any contraction that may be here witnessed be entirely of the passive kind, and consequently the movements here noticed are not worthy of implicit reliance. But it is more easy, and quite as satisfactory, to bring a muscle under inspection, which is still *in situ* and in equilibrium with its antagonists: in such, contractile force is being still exerted, though its full effects are prevented from taking place. This may be done in various small animals: perhaps the tail of small fish, or of the tadpole of the common frog, is the best adapted for the purpose. In the latter, deprived of its integument, we have obtained such a view, and have found the contraction to be quite uniform throughout, the transverse stripes being stationary and equidistant. This is nothing more than might have been expected on *à priori* grounds. The contraction, being the effect of the passive exercise of the property shared equally by all parts of the tissue, would be equal in equal masses; and, as the elementary fibres are of precisely equal width and substance from end to end, no part of them could predominate in action as long as only the equable stimulus coincident with their natural state of tension were applied. It may be concluded, therefore, that passive contraction is attended by a movement absolutely uniform throughout the whole mass of an elementary fibre, or of a muscle.

In *active contraction*, the case is far otherwise, as may now be considered proved by a considerable body of evidence.

It might be argued, prior to direct proof, that active contraction must be partial, at least at its commencement; because the stimuli which occasion it cannot, in their very nature, be applied to every particle of the fibre at one and the same instant of time.

Certain features of the phenomena witnessed under the microscope in fragments removed from the body, and contracting in water, have a close bearing on the present question. It has been already said, that such contractions are uniformly partial; but they present two further varieties, either remaining in the part where they first occur, or leaving it as they advance to others in the neighbourhood. The accidental circumstances under which the fragments are placed, explain these varieties. In the former case, the ends of the fragments happen

Fig. 49.



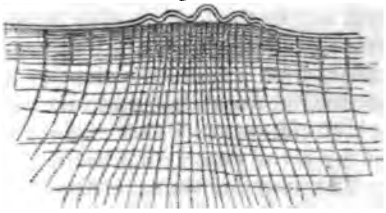
Fragment of an elementary fibre (from the Eel) partially contracted in water. Magnified 300 diameters.—*a.* Uncontracted part. *b.* Contracted part, along the border of which the sarcolemma is raised from the surface by the water that has been absorbed, that has thereby caused the contraction, and by it has been expelled from the contractile mass.

y movable, and are drawn towards each other, according to nt of contraction occurring in particular spots; and, as the : force leaves these spots and engages others, the ends con- pproximate, the parts once contracted remaining so, because force to extend them. Hence the contraction appears per-

atter case, certain parts of the fibre (as its broken extre- fixed more or less firmly, so as to offer a resistance to the n that takes place; this resistance enabling the contractile ıncing to new parts to obliterate the traces of contraction in in which it is subsiding, by stretching them. The ends come fixed in consequence of their being the first to thicken raction, and from their thus receiving the pressure of the mica or glass with which it is requisite to cover the object; are the first to contract, because irritated by being broken, e water, which is absorbed soonest where the sheath is de- This fixing of the ends brings the fibres in question nearly ondition under which they exist in the living body, where ady been explained that there is always a resistance to be in active contraction. This particular variety of the phe- therefore, deserves special study. Those animals whose re most tenacious of their contractility are the best suited nation; and, among these, the young crab or lobster may asily obtained.

elementary fibre from the claw, laid out on glass, and then ith a wet lamina of mica, the following phenomena are be observed. The ends become first contracted and fixed. tractions commence at isolated spots along the margin of the ch they cause to bulge. At first they only engage a very nount of the mass, spreading into its interior equally in all , and being marked by a close approximation of the trans- es. These contractions pull upon the remainder of the fibre e direction of its length, so that along its edge the transverse the intervals are very much widened and distorted. These ns are never stationary, but oscillate from end to end, relin- n the one hand what they gain on the other. When they ous along the same margin, they interfere most irregularly another, dragging one another as though striving for the the larger ones con- vercoming the smaller; iding as though spent, again by new spots of n; and again, after a od of repose, engaged rn by some advancing is is the first stage of omenon (fig. 50). At ent stage, the ends of commonly cease to be consequence of the in-

Fig. 50.

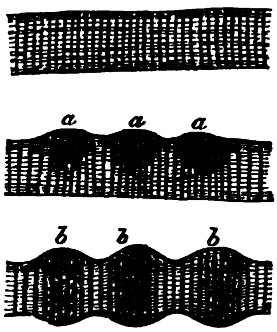


Border of an elementary fibre of a young Crab, showing a spot of contraction, and the sarcolemma elevated in the form of bullæ by the expressed water.—Magnified 300 diameters.

termediate portions, by their contraction receiving some of the pressure of the glass. The contractions, therefore, increasing in number and extent, gradually engage the whole substance of the fibre, which then is reduced to at least one-third of its original length.

The muscular tissue in these animals is comparatively tough; but where it is more fragile, as in the frog, it may give way in the intervals between spots of contraction, and become ruptured and disorganized in various degrees. (*Phil. Trans.*, 1840, p. 490, pl. xix. fig. 75.) In fishes we have seen a succession of phenomena similar to what has been described in the crab; waves of contraction advancing and receding, but gradually augmenting in bulk, till the whole fibre was finally contracted (fig. 51).

Fig. 51.



Stages of contraction seen on one occasion in an elementary fibre of the Skate. The uppermost state is that previous to the commencement of active contraction.
a. a. a. Successive "waves" of contraction seen moving along one margin of the fibre, marked by a bulging of the margin, by an approximation of the transverse stripes, and by a consequent darkening of the spots.
b. b. b. Similar "waves" still moving along the fibre, but engaging its whole thickness.

In all these examples, as long as the ends of the fragment are fixed, and will not yield to the convellent force, that force is seen to be exerted in a momentary manner in successive portions of the mass. In proportion as they yield to it, the resistance which enabled the contraction of new parts to stretch those from which it was receding is removed, and the appearances of contraction remain. A distinction is required between the contractile force and the contraction resulting from its exercise. The latter will be permanent, if no force from without be exerted to obliterate it by stretching; for a contracted muscle has no power of extending itself; there is no repellent force between its molecules. From these phenomena, therefore, it is possible to eliminate the appearances resulting from a subsided force and to judge of the mode and duration of action of the force itself. Thus sifted, they prove that, even when directly stimulated by water after removal from the body, a muscle contracts in successive portions, never in its totality at once; and that no particle of it is capable of exhibiting an active contraction for more than an instant of time.

The appearances presented by muscle that has been ruptured by its own inordinate contraction in fatal tetanus, in the human subject, will supply the link wanting to connect the foregoing phenomena with those occurring in healthy contraction during life: for tetanic spasm differs from sustained voluntary contraction, only in its amount and protracted duration, and in its being independent of the will; none of which circumstances are of essential importance in regard to the nature of the act of contraction itself.

The muscles are so arranged in the body, that no amount of contraction which the mechanism of the bony and ligamentous framework will permit one of them to undergo, can by possibility occasion the rupture of an antagonist, provided it remain relaxed: to be rup-

he antagonist must be itself contracted. But a muscle, if ed beyond its natural amount, may be so resisted by mechani- 'ers, in or out of the body, as to rupture itself. Hence, the ion of a muscle is a necessary condition, and generally the l cause of its own rupture: the other condition being a force than the tenacity of the ruptured part, holding its ends ; which latter may be either the active or passive contraction onists, or mere mechanical resistance: but it is evident, that, iscle to be ruptured by its own contraction, that contraction partial, as is shown in the case of the frog's muscle, already ed.

camination of muscle ruptured in tetanus is found to bear out servations in the fullest manner. (*Phil. Trans.*, 1841, p. 69.) mentary fibres present numerous bulges of a fusiform shape, i the transverse stripes are very close together. These swell- contracted parts, are separated from one another by intervals us lengths, in which the fibre has either entirely given way, ore or less stretched and disorganized. These appearances with after all contractility has departed ; they are the vestiges pasm during life. Yet in other muscles, which have been convulsed, but not ruptured, they are not found. Their e is, therefore, the result of the rupture. They admit only of owing explanation: the contractile force has operated at the ound contracted, and, by its excess, the intermediate portions en stretched to laceration. Having once given way, the con- parts have become isolated, and can no longer have been d after the subsidence of contractile force ; they consequently ie form and appearances they possessed, when surprised, as by the rupture they have themselves produced of the inter- parts.

osing, for a moment, that active contraction were an univer- equable act, and that, by the superior power of an antagonist, muscle had been ruptured, the appearances resulting would ly be entirely different from those now detailed. The fibres the ruptured point would have their transverse stripes uniformly nated.

y be concluded from the preceding facts,—1st. That active ion never occurs in the entire mass of a muscle at once, nor hole of any one elementary fibre, but is always partial at any ant of time:—2d. That no active contraction of a muscle, r apparently prolonged, is more than instantaneous in any is parts or particles:—and therefore, 3d. That the sustained contraction of a muscle is an act compounded of an infinite of partial and momentary contractions, incessantly changing ce, and engaging new parts in succession ; for every portion ssue must take its due share in the act.

phenomena yet remain to be mentioned, which, by admitting sfactory explanation on this view of the subject, give strong y to its correctness.

irst is the *muscular sound*, heard on applying the ear to a

muscle in action. It resembles, according to the apt simile of Dr. Wollaston, (*Phil. Trans.*, 1811,) the distant rumbling of carriage-wheels; or rather, perhaps, an exceedingly rapid and faint tremulous vibration, which, when well marked, has a metallic tone. It is the sound of friction, and appears to be occasioned by those movements of the neighbouring fibres upon one another, with which the partial contractions must be attended in their incessant oscillations.

The other phenomenon is one whose existence has been recently ascertained by MM. Becquerel and Breschet, (*Recherches sur la Chaleur Animale. Archiv. du Muséum*, tom. i. p. 402,) viz., that *a muscle, during contraction, augments in temperature.* They have found this increase to be usually more than 1° Fahr.; but sometimes, when the exertion has been continued for five minutes, (as the biceps of the arm, in sawing a piece of wood,) it has been double that amount. This development of heat may be in a great measure attributable to, and even a necessary consequence of, the friction just alluded to.

Thus it would appear, that in active contraction there is a disturbance of the state of equilibrium, or rest, by the application of a special stimulus to certain portions only of each fibre; by which first these portions, then others in succession, are made to contract strongly, and to pull on the extremities of the fibre through the medium of the parts not so contracted. The contractions undulate along the fibre from the point stimulated, and there is always a considerable part of each fibre uncontracted. This will account for the remarkable fact, that detached fragments of the voluntary fibre will contract by two-thirds of their length; though an entire muscle, in its natural situation, cannot shorten by more than one-third. This great capacity of contraction in the *tissue* would be without a purpose, if it were not that it only admits of momentary exertion, and therefore requires that in the *organ* successive parts should take up the act, and by so doing, render it, as a whole, continuous. In an active fibre the contracting parts are continually dragging on those in which the contractile force has just subsided, and which intervene between them and the extremities of the fibre. These are thereby instantly stretched, and come to serve the temporary purpose of a tendon; but one which resists extension more by its passive contractility than by its mere tenacity. It is these parts which in tetanic spasm suffer laceration; which happens in consequence of the contraction excited by the vis nervosa being then too powerful to be resisted by the passive contractility.

The preceding account of the minute changes occurring during contraction rests on data furnished by the striped form of muscular fibre; but there is nothing contained in it which seems at variance with the little that is positively known regarding the contractions of the other form. The differences between the contractions of the two varieties are almost certainly confined to the manner of exercise, and do not extend to the essential nature of the act. Though the unstriped fibre has not been studied by the microscope, during its active state, with the same success as the other, yet the similarity of the gross changes observed in it by the naked eye, to those seen in volun-

tary muscle, forbids us to doubt the identity of the phenomenon in all that is essential to it as an act of contraction.

From the knowledge we possess, we are perhaps entitled to hazard some further conjectures respecting the differences in the mode of exercise of the contractile power in different cases. In whatever that mysterious power may consist, it would appear that the structural modifications of the two kinds of fibres are intimately connected with the manner in which it is capable of being exerted. Wherever the striated structure occurs, we witness an aptitude for quick, energetic, and rapidly repeated movements; while, where it is deficient, they are sluggish, progressive, and more sustained.

The varieties in the character of contractions performed by striated muscles are very striking, especially that of the heart, as compared with the prolonged action of the voluntary muscles. In both, there is an alternate momentary action and repose of every contractile particle: but in the heart the contraction is universal at one instant, and the repose equally universal at the next; while, in the prolonged action of the voluntary muscles, contractions of certain parts of each fibre always co-exist with repose of other parts.*

The contractions of voluntary muscles differ greatly from one another in duration, energy, and extent. Dr. Wollaston (*Philos. Trans.*, 1811), was of opinion, that the phenomenon of the muscular sound affords a proof that the *duration* of a muscle's contraction depends on the application to it of a succession of distinct impulses; and this idea, according very nearly, as it does, with the later evidence of observation, appears, on the whole, the most satisfactory that has been advanced on this abstruse subject. He also thought that the intensity of a contraction corresponds with the rapidity with which these impulses are transmitted to it; and this likewise may be, in part, true. But there is, in addition to this, in all probability, a difference in the intensity of the stimulus itself in different cases, producing a difference in the size of each wave, a difference in the amount of contractile energy exerted in each, and a difference in the rapidity with which the waves oscillate along the fibre. The *extent* of the contraction (the duration and intensity being the same) will manifestly depend on the amount of the length of the fibre which is contracted at once; but we are ignorant whether this variation in amount is effected by a variety in the number of waves, or in the extent of the fibre engaged by each of them.

In describing the white fibrous tissue, we remarked the facility with which its fibres are thrown into a wavy or zigzag course when their ends are brought near together. The same thing occurs in the nerves, and may be observed in almost any flexible non-elastic cord. The muscular fibre easily assumes this zigzag course, when its ends are approximated by any other force than its own contractility. It may thus be at any time thrown into zigzag, long after it is quite dead, and has lost all its contractility: and, in general, such zigzags

* By the expression "universal at one instant," we do not mean *absolutely* so; for observation, and the presence of the muscular sound, both declare that the contraction, even of the heart, though so apparently momentary, is progressive.

occur at pretty regular intervals, determined by the force employed and the flexibility of the tissue; and, when several fibres are lying in contact, their zigzags usually correspond.

Now, such zigzags have been frequently observed in the living fibre, of course accompanied with an approximation of its extremities; and some physiologists, mistaking the effect for the cause, have concluded the zigzags to have occasioned the shortening. Dr. Hales, and, long after him, Prevost and Dumas, examined this appearance in the flat abdominal muscle of a frog, laid on glass, and made to contract by a galvanic shock; and, noticing that the angles of the zigzags corresponded in many places with the transit of nerves across the fibres, they concluded that an electrical current, passing from one to the other, occasioned the flexion of the fibres at the points of contact.

This hypothesis, when first proposed, attracted great regard, from its appearance of simplicity, and from its falling in with the then favorite notion of the identity of the nervous influence with some form of electricity; and without sufficient caution it was very generally adopted. The facts previously stated, however, completely overthrow it, and render an explanation of the causes of the error scarcely more than historically interesting. It would appear that the galvanic shock, when passed through a mass of fibres, affects them unequally, some only being contracted by it: but these, by their cellular and vascular union with others, draw towards each other the ends of the uncontracted ones, and, of course, throw them into zigzag; and it is most natural that the passage of nerves or vessels across them should determine the flexures to take place at this or that particular point. When some fibres are straight and others zigzag, and yet the ends of all equidistant, it is clear that the straight ones are the short or contracted; the zigzag, the long or relaxed. So, also, when a living muscle is laid bare *in situ*, the air excites tremors and a zigzag appearance on its surface, by the different fibres taking on non-simultaneous contractions.

Schwann (*Müller's Physiology*, by Baly, p. 905), contrived an apparatus by which he could estimate the varying force of contraction which a muscle could evince under the same stimulus, (an electric shock of a given power applied to the nerve,) when its length was varied, by its passive contractility being balanced by different weights. He sought to discover whether the contractile force was increased as the contracting parts approached each other more nearly. If he had found it so augmented, there would have been some reason for connecting contractility with the other forces of attraction with which we are acquainted, the power of which increases with the nearness of the points attracted, in the ratio of the square of the distance. But the results of several ingenious experiments were quite opposed to this notion; proving that, within certain limits, the power of a muscle to contract under a stimulus is greater in proportion as it is less contracted, and that it diminishes as the amount of contraction increases.

Considering, as we are perhaps entitled to do, that an equal mass

each fibre, say one-third, was in contraction at any one instant by ch application of the stimulus, we may reduce the result of these periments to an estimate of the passive contractile power under fferent amounts of stretching; for then the varying amount of aggrete shortening under the same stimulus would indicate the varying nount of resistance to elongation afforded by the intermediate twoirds to the same amount of active contractile force in the one-third.

It is clear, from that which precedes, that contractility is a property siding in the sarcous tissue by virtue of its chemical constitution, d that it is capable of being called into action by other stimuli beles the nervous. That it departs with life, is a proof that those tions of waste and nutrition, concomitant with the flux of life, are sential for its integrity. We know that contractility is exhausted th by disuse of a muscle, and by over-use consequent on overimulation; and in no other way can these opposite causes act than their both interfering with healthy nutrition. That they do thus t, is rendered probable by other proofs. It has long been known at cutting off the supply of blood from a muscle destroys its conactility; that unnatural temperature has the same effect; and, in neral, that all causes affecting nutrition affect also contractility in e same degree.

The contractility of a muscle has also invariably a certain comexion or character connected, we might almost say, with the vigor, it at least with the character, of the nutrient process in the particur muscle. This fact has been ably illustrated by Dr. Marshall Hall, ee article "Irritability," *Cyclop. of Anat. and Phys.*,) who nevereless is opposed to the great conclusion which we consider to flow om it, that contractility is proportioned to the activity and perfection f the nutrient function.

If we suddenly check the supply of nutrient material to the muses of various animals, in the same state as regards previous stimution, and in such a manner as not to stimulate the muscles in so ing, we shall find that their contractility, as evidenced by their ntracting under a given stimulus, endures through very unequal riods of time. Thus, in the bird it is very evanescent; in the sect, also, it is very evanescent; in the mammal less so; in the ptile it lingers longer; while in the fish and crustacean it is in genel very enduring.

The degree in which oxygen is admitted to the tissues in these anials, corresponds in the main with the scale thus designated by the lative endurance of the contractility of their muscles. Nothing is ore probable than that the amount of oxygen admitted to the tissues may be taken as a fair estimate of the activity in them of the ocesses of waste and assimilation. Now, we know that the vitality the tissues does not cease immediately on their supply of nutriment ing cut off; that death of the whole animal, as an individual, is not cessarily attended with simultaneous death of every part; that *soatic* death generally follows *systemic* death from the functions being longer concatenated in mutual dependence; and it is entirely nsonant with facts to suppose that the endurance of the vital funcons in the tissues after systemic death is proportionate to the slow-

ness with which they are ordinarily performed. The close correspondence, therefore, between the duration of contractility and the slowness of the nutrient function in various animals, is a strong evidence of the dependence of the one on the other.

And it is extremely interesting to observe, that not only does a less arterial character of the blood co-exist with a more enduring contractility, but also that there is less of it supplied to the muscles, for the above scale corresponds also with that in which animals are ranged in regard to the size of the elementary fibres; and we have already seen that the vascularity of a muscle is inversely as the thickness of its fibres.

Thus we have animals ranged in the same series, whether we estimate it by the duration of contractility, the degree of the oxygenation of the blood and tissues, or the quantity of blood sent to the muscles, viz., birds, insects, mammalia, reptiles, fish, and crustacea. The meaning of this correspondence may be further illustrated by the phenomena of hybernation, in which all the functions are held enchained, and we are certain that nutrition proceeds with extreme languor. In the hybernating animal, contractility is very enduring, as compared with that property in the very same organs when in a state of greater vital activity.

Nor must the evident relation subsisting between fibrine and the sarcous tissue, in respect of their vital properties, be passed over in silence. In chemical constitution they may be said to be identical; and there seems no doubt that muscle is formed by the direct deposition in a solid form of the fluid fibrine of the blood, under the elective attraction of the previously existing tissue. Now, in birds, the blood, *i. e.*, its fibrine, coagulates, or assumes the solid form, very quickly when it is withdrawn from the vessels, in mammalia less so, and in reptiles and fishes very tardily, if in these several cases it be placed in similar circumstances. A fatal stroke of lightning, which instantaneously destroys contractility in the muscles, prevents also the coagulation of the blood. In the same person, under health and disease, the blood may vary much in the speed with which it coagulates, according to its chemical constitution, the amount of oxygen accumulated in it, and the activity of the vital processes: and, after death, the coagulability of the blood, and the contractility of the muscles, have a general correspondence, which has been even made the basis of an hypothesis, ascribing the *rigor mortis*, or the dying act of contraction, to coagulation of the blood.* It will be subsequently explained (see chapter on the *Blood*), that the fibrine of the blood, on becoming solid, acquires for a brief period the property of contractility; and this in very different degrees, according to varieties in the same causes which affect the speed of its coagulation. No one will pretend that this is not as much a property of living fibrine when solid, as that of coagulating is of the same substance when fluid; and the correspondence between the coagulated living fibrine of the blood and the living sarcous tissues in chemical constitution, in the possession

* Orfila, Béclard, and Treviranus hold this view, which Müller seems to regard as not untenable.

contractility, and in the modes in which that vital property in both affected by similar causes, adds strong confirmation to the opinion e have expressed, that contractility is a property of the living musılar substance as such.

But contractility does not vary in its durability alone; it also prents great differences in regard to its *aptness to excitation* by stimuli: ıd it would appear that these characters are always, *cæteris paribus*, an inverse relation to one another. In birds and insects, which ıve for the most part to sustain themselves by very energetic and pid muscular movements in the air, the excitability is extreme; ıd certainly the motions performed by these creatures far exceed in ecision, regularity, and frequency those of any other animals.

The *rigor mortis*, or stiffening of the body after death, is due to a ontraction of the muscles. If the contractility of a muscle be enduring, the rigor comes on late and lasts long; but if it be evanescent nd its character excitable, the rigor begins very soon and quickly rminates. This is true in different individuals and classes of animals, nd corresponds entirely with what we have already said of the varieties of this property. Its cause is obscure, and may be complex; but s resemblance to the contraction of fibrine after recent coagulation too obvious to be overlooked. Its nature is shown by the preceding bservations (p. 170).

We have the power, at will, under certain limitations, of producing, checking, and regulating the amount of contraction in the voluntry muscles; and, as a necessary part of this power, we are able to ppreciate, by certain sensations originating in the muscles, what preise degree of contraction is present in each. This latter is only that ıodification of common sensibility which belongs to muscle. It has een termed the *muscular sense.* In it we possess a most important id to the sense of touch, being able accurately to vary the posion and amount of pressure on external objects in voluntary accordnce with the impressions these communicate to the sensorium through he tactile nerves; and by it we are able to estimate with nicety the mount of muscular power required to balance various resistances, as reight, &c. In general, these resistances must be brought into relaion with the muscular sense through the organ of touch, which is dapted to this purpose by its superficial position on the body. But he powers of the muscular sense, isolated from tact, are exhibited, ı its enabling one to estimate the weight of a tumour developed in ıe interior of the limb, and in general the resistance afforded by the reight of one part of the body, or the action of one muscle or set of ıuscles to that of another. Hence a principal source of the marvelous power which all animals possess of associating the various parts f their bodies in numberless combinations of harmonious movement.

Of some varieties of muscular movement.—Having described the ifferences between the movements of active and passive contracon, we shall now be more able to refer to their proper causes those arieties of movement by which certain muscles or classes of musles are distinguished. In briefly adverting to these, we shall have glance at some collateral considerations regarding the mode of their

connection with the nervous system, which cannot be fully understood without reference to what will be afterwards said under that head.

The *action of the sphincters* of the anus and bladder seems, at first, peculiar. They are constantly contracted, except during the passage of the contents; and yet no fatigue attends this persistent action. The explanation is very simple. They remain contracted unless the contained matters are forced within them by a superior power. Now, their mass, and therefore their contractility, is superior to that of the wall of the cavity above; consequently their passive contraction endures while that of the parts above is being gradually mastered by the accumulation of the feces or urine. But, when these excretions at length excite active contraction in the walls of the cavity containing them, this overcomes the passive contraction of the sphincters, and the evacuation occurs. The sphincters have striped fibres and voluntary nerves, by means of which we can for a time add active to passive contraction, and thus retard the expulsion; but, as the accumulation proceeds, this power is diminished or lost, and the sphincters yield. The levator and sphincter ani frequently aid the accumulation of the feces by temporary active contractions, by which the feces tending to dilate the sphincter are pushed backwards for a while. The rectum is thus preserved empty until the period immediately preceding defecation.

In paralysis of the lower part of the body from disease or injury of the spine, the voluntary power of the sphincters is lost, and the feces and urine pass involuntarily. But this is no proof, as is commonly imagined, that the ordinary contraction of the sphincter is an active one, performed in obedience to a continuous nervous stimulus. The difference is, that it can now induce no active contraction through the nerves, to counteract temporarily, and in obedience to the will, the active contractions of the parts above, which are not under the influence of volition, and are not paralyzed. Hence, whenever the feces are driven against it, it gives way, against the patient's will, and (if the sensitive nerves are also paralyzed), without his knowledge.

Contractions are called *peristaltic* or *vermicular*, which advance through a muscle in a slow and progressive manner. When analyzed closely, we shall find that they are only a variety of the active contraction already described. If a number of striped fibres are arranged in a long series, and are contracted in succession (as in caterpillars), the resulting movement is vermicular; but in the higher animals it is only in the hollow unstriped muscles that this variety of contraction occurs; and the best example of it is in the alimentary canal. On laying bare the intestines of an animal just killed, we observe successive waves of contraction advancing down the tube, and urging its contents along. They appear to be rendered more active by the contact of the cold air; but may be re-excited, when they have almost subsided, by irritation of the sympathetic ganglia, from which the muscles are supplied with nerves. If a single point of the intestine be touched, a contraction presently occurs there, which moves on-

ls to a considerable distance, and is often succeeded by others taneously arising.

is impossible not to remark the close similitude between these ractions and those visible by the microscope in the striped eleary fibre. We have here on a large scale the wave-like characiere exhibited. A contracting voluntary muscle exposed to view bits a tremulous motion, and it may be a question how far this depend on numerous contractions strictly vermicular, affecting ssive sets of fibres, but prevented, by their irregularity and of coincidence through the whole muscle, from appearing so to ye. When the pectoral muscle is struck, a knot-like contraction moves off in a slow manner in the direction of the fibres. Peric contraction is coincident in a large number of contiguous s; and its progressive character is more easily perceived in conence of the arrangement of the fibres around a compressible cav- The contraction appears more sluggish than other forms; but, e are ignorant of the length of each unstriped fibre, we cannot whether this slowness is in advance along each one, or merely one to another.

e contraction exhibited by the muscles in question is always of eristaltic character, by whatever stimulus excited; and its type refore probably derived from some peculiarity in the fibres thems, as in their arrangement. But it is remarkable that the stimuli h usually excite it, are applied in succession to different parts, are thus entirely suited to the production of the peristaltic conion. We have a striking example of this in the œsophagus, h is simply a tube of transmission, and not intended to delay the The pellet, when thrust into it by the muscles of the pharynx, nds its fibres, which, then contracting upon it, propel it into a portion ready to receive it. This in its turn contracts, and urges ng; and so on, until it is conducted to the stomach.

this instance, it is evident that the propelled substance is itself timulus to the successive contractions. This it may be, either stending the fibres, and so acting locally upon them; or else by essing the nerves of the membrane touched, in such a way as to e a nervous stimulus to the muscular coat at each particular part, e proper moment. As the food is not propelled if the nerves ivided, there can be little doubt that the latter is the true explan.

e contraction of the bladder occurs after a gradual distension, though very temporary, is probably of the true peristaltic kind. more protracted action of the *uterus* is undeniably so. In preganimals this may be as distinctly perceived as in the intestines, t probably occurs during the gradual development of the muscuructure as pregnancy advances; but at length a very powerful lse occasions the expulsion of the young, and the uterus subsetly remains contracted, because no force distends its fibres. The *pains* mark the final efforts of active contraction. Atrophy of issue then occurs, as its development had done, in accordance other laws.

Rhythmical contractions are those which succeed one another after regular intervals of repose. The muscles of respiration and the heart exhibit them through life, which would cease if they were intermitted even for a brief period; for the oxygenation of the blood, and the dispersion of that fluid through the substance of the various organs, must incessantly proceed. Hence neither is an act of the will required for their production, nor could it under any circumstances prevent them. The heart beats independently of our consciousness or control; but the respiratory actions may be hastened, or retarded, at will, though not stopped. This voluntary power is given because these muscles are required in various movements of the body, either alone, or in aid of others; they minister to other functions besides that of respiration. The voluntary, or irregular action, however, is entirely subordinate to the involuntary and rhythmical.

The rhythmical character of the respiratory act is to be explained by reference to the stimulus by which it is ordinarily excited. This is an impression made on the internal surface of the lungs by the deteriorated air, and recurs periodically from the change induced in the inspired air by its contact with the blood in the air-cells.

Though the heart is in no respect under voluntary influence, yet emotional and instinctive impulses easily affect it: its action is throbbing, tumultuous, or feeble. These impulses act through the cardiac nerves, which, if stimulated mechanically, will excite contractions in a heart removed from the body, and which has almost ceased to beat: but, under all circumstances, the action of the heart is rhythmical. The cause of the rhythm it is exceedingly difficult to resolve. This variety of contraction is coincident with periodic distension of the cavities, and impressions on their lining membrane. But it continues long after the heart is empty, and its nerves cut. Hence, whatever share these circumstances may have in giving the rhythmical character in the natural condition of the parts, they are certainly not essential to each individual pulse. It is singular that a mechanical stimulus applied once to the heart will often excite a series of contractions after they had ceased, or modify the rhythm of those previously existing; its effects being thus prolonged through many beats.

In reviewing the actions of the voluntary muscles we may remark the following interesting circumstances:

1. *As to association of movements.*—By the mechanical arrangements of the muscles on the bony framework, and by the peculiarity of their several nervous connections, they are rendered capable of conspiring in those combined actions which produce the various attitudes and general movements of the body. There are few muscular actions, indeed, of an entirely solitary kind. In the animation of the features under the passions, in articulation, in deglutition, in respiration, and in numberless other cases, we have examples of this association of many actions to the production of one effect. Even the consent of the fibres of a single muscle in contraction is an instance of this fact. Among innumerable other proofs of harmonious design in the construction of the animal body, this might be singled out as a most convincing one, that not only are the hard levers, and their

ɪints and motive engines, so built up as to be entirely proportioned ad adapted to one another in shape, strength, and position, and a rstem of nervous communications established, by which the motor ower can be at once excited, prolonged, or controlled in any particu- r muscle; but that the mere will, an emotion, an excitement of sense, r even one unconsciously received, is able, by the correspondence cisting between the different parts of the nervous system, to pro- uce associated actions in precisely those parts mechanically adapted move in concert, and this with exquisite exactitude as well as va- ety.

Such is the nature of the nervous communications between certain uscles, that, in numerous instances, one cannot be stimulated to ontraction without others contracting of necessity at the same time. 'his depends very generally on the mechanical disposition of mus- les, obliging certain of them to fix a point from which others may ct. Thus the scapula is continually being fixed by the muscles onnecting it with the trunk, in order that the arm may be wielded pon it. Thus, also, the brow cannot be elevated by the frontalis rithout the occipitalis fixing the intermediate tendon. But, in other ıstances, this necessary consent is dependent on the symmetrical rrangement of similar parts on the two sides of the body. Some ersons cannot close one eye, keeping the other open; or dilate one ostril without the other: we cannot look up with one eye, and down rith the other; nor compress the abdominal cavity by the muscles of ne side without those of the other. There is, indeed, a general tend- ncy to symmetrical movement, which it is the part of education nd habit to overcome within certain limits. The movements of the ands—those wonderfully versatile instruments of man's intellect— re, in his state of infancy, generally symmetrical. The unsymme- ical actions of walking are a slow acquisition. Most motions that re symmetrical are also harmonious; but there is one example in 'hich *symmetry* gives way to *harmony* of movement, viz., in the teral motions of the eyes, where symmetry would produce a squint, nd derange the consent of the images on the two retinæ. Here, ıerefore, by the distribution of the nerves, non-symmetrical muscles re made to produce a harmonious movement.

The various attitudes of man may here be briefly explained. Mus- ular actions associated to produce an attitude are styled *co-ordinate.* 'hey conspire in obedience to the particular organization of the nerv- us and muscular systems; and the resulting postures are natural, nd perfectly accordant with the wants and habits of the species. Iost attitudes, if perfectly natural, are graceful, just as external fig- re is graceful; unnatural attitudes are more or less constrained, or wkward. The co-ordinate, like other movements of the voluntary uscles, are liable to be influenced by passions and affections of the ind. Hence the internal commotions of the soul betray themselves the attitudes of the body as surely as in the lineaments of the coun- nance.

In considering the different attitudes, it is to be remembered that ıe human body is not withdrawn, either by its organization or vital

endowments, from the operation of the general laws of matter; and, accordingly, that the muscular actions occurring within it are all adapted to act upon its several parts, as upon masses of certain shapes, sizes and weights. In all attitudes the centre of gravity must be maintained within the base of support.

In *standing*, the base of support is the space included between the extreme points of the feet. The feet are separated, and the toes turned outwards to increase it. If the body be pushed aside, the foot is instantly carried under it, or it falls; and if motion be unexpectedly given to the feet, while the body remains at rest by its inertia, (as when a boat in which we are standing is suddenly shoved off from the shore,) the body falls. In standing upright, both legs are kept extended, and the spine and head erect: if the muscles that effect this be suddenly paralyzed, as when a man is shot dead, the head droops on the chest, the curves of the spine are increased by the pressure of the superincumbent weight, and the whole trunk approaches the ground by bending the joints that were before extended.

The muscular action required to maintain the erect posture of the body is very great. This is shown by the fatigue that ensues on an attempt to remain perfectly still in the erect posture, even for a very short time. In fact, though we can stand long at a time, it is only by frequently relieving one set of muscles, and bringing another into play, as every one may convince himself by attention to his own case. We throw the weight of the body first on one leg, then on the other; we change the position of the feet, and of the ankle, knee, and hip joints, as well as of the rest of the body.

Under all these movements, the centre of gravity has to be kept within the basis of support; and, to effect this object, the different muscular actions on which the erect posture depends must be exquisitely balanced against one another, and, when one is altered, the rest must be re-adjusted in harmony with it. In the practised tumbler, balancing himself on a point, or the opera-dancer, poised on a single toe, we have the most beautiful examples of the precision of this adjusting power. Where the basis of support is ampler, it is less apparent, but not less real.

The various parts of the body are *weights*, and, in the muscular adjustments, are treated as such. By their symmetrical development on the two sides, they are naturally balanced, and thereby carried with less muscular effort. When two equal artificial weights are fixed on opposite sides of the body, equidistant from the centre of gravity, (as when buckets are suspended from a bar passing across the shoulders,) the mere weight is all that the muscles have to support: but, if one be removed, a corresponding inclination of the body must instantly be made towards that side to counterpoise the other; and for this a sustained muscular effort must be made in addition to that required for the support of the remaining weight. Now, a part of the body on one side (say, an arm), by being carried from the centre of gravity, may disturb the equilibrium of weight, just as moving the weight on a scale-beam disturbs it: that side of the body becomes relatively heavier, and an inclination towards the opposite is rendered

:essary. In all the changes of attitudes, similar adjustments are ıng constantly made; and, in general, the more accurately they are ected, and the more economically in regard to the outlay of mus- lar power, the more graceful and pleasing are the movements and stures themselves.

In the associated *movements of progression*, or locomotion, the same cumstances are observed: walking, running, and leaping are but ferent modes in which the body is repeatedly inclined by muscular ort beyond the basis of support; and this basis brought again and ain, by muscular effort, under the centre of gravity.

The movements of ordinary *walking* may be readily analyzed. ıppose we commence by advancing the left leg. We first slightly ise the left heel, and bend the left knee, to disengage the limb from ıe ground; throwing the weight of the body on the right limb, and, ıerefore, inclining the body towards the right side. The body is ow raised by an extension of the right ankle-joint, effected chiefly y the calf; the ball of the foot resting on the ground, which serves s a fulcrum. At the same time the body is thrown in advance of his fulcrum, and would fall, were it not that the left leg is now rought under it, and receives its weight, by which the body is in urn inclined to the left. The right leg, which had been extended, s then bent, raised from the ground, and swung forwards, ready gain to sustain and project the body, when the left leg has gone hrough a similar movement. In *running*, the muscular actions are erformed in a similar succession, but more rapidly and more vigor- usly. The body is more bent forwards, and its weight made more fectually to aid progression. In *leaping*, the body is projected by a ıdden extension of both the lower limbs, and raised, for a brief ne, entirely from the ground, the feet being advanced again in time receive its weight as it descends.

2. *As to the manner in which movements of the voluntary muscles are cited.*—These muscles are subject, through the motor nerves, to e influence of several remote stimuli, already enumerated, and the ief of which, *volition*, gives its name to the class. These stimuli, the healthy body, impress the motor nerve in the nervous centre, d the effect is a contraction of the muscle. By an exertion of the ll we can contract more or fewer muscles at once, and to any de- ee, within certain limits: we can contract antagonist muscles toge- er, or alternately, and through a longer or shorter period.

But every voluntary muscle is subject to other influences more rtain and more powerful in their operation than the will, and to ıich the will has often to yield. The wonderful and characteristic ovements of the body, and especially of the features under the ıpulses of passions and emotions, are all involuntary, of which the st proof is to be found in the very partial power the will has of straining them. To imitate the movements of passion is a task of treme difficulty; and those actors succeed the best who lose them- lves the most in their characters, that is, who the most completely sume for the time the passion they design to portray. Without is quality the most elaborate imitation is cold, and fails to touch our

13

sympathies. The genius of the histrionic artist consists chiefly in this power.

Many movements ensue involuntarily when certain impressions are made on the surface of the body, or in any part of its interior, either by external or internal causes. Such impressions are usually attended with consciousness, but sometimes not; so that there is no reason to believe that perception of the impression is in any way essential to the production of the movement. All such movements are termed *reflex*. The contraction of the esophagus in swallowing is an example of them without consciousness. The sudden inspiration that follows a dash of cold water on the skin, and the writhings produced by tickling, are instances attended with consciousness. All muscular actions consequent on pain, and which are not the immediate act of the will, are similar in kind, though the stimulus producing them is unnatural.

Reflected movements are sometimes called *instinctive;* but this term is better limited to actions resulting from a propensity in the mind, of the meaning of which we are ignorant, but which we follow blindly without reference to consequences. Such propensities are developed in animals much more than in man; and in man more during his infancy than in his mature state, when reason asserts her domination over instinct. Instinct exhibits foresight; but it is the foresight of the Creator, and not of the creature. It is the reason of God working with the material instruments of the creature's reason, independently of the creature's will. Hence the movements consequent on its impulses have all the concatenation and character of movements impelled by reason through the will; while they are altogether independent of the will. Instinctive movements approach the most nearly to voluntary ones.

Thus passion, emotion, reflected stimulation, and instinctive impulses will all excite involuntary movements of the voluntary muscles; but, in the natural state of the body, all these causes are found acting in harmony with one another, often conspiring to produce the same movement. The power of the will to control them is but slight, and in some cases null. It differs with the original strength of that faculty, with the temperament of the individual, and especially with the degree in which it has been affected by habit. The power of this law is in nothing more conspicuous than in its influence over the human will. A frequent and energetic repetition of voluntary acts of control over the involuntary movements of passion, emotion, and instinct, is invariably followed by an increased power of control, and *vice versâ*. This also extends (but in a less degree) to those movements of voluntary muscles, consequent on reflex stimulation, which are not essential to life.

When movements, which have been at first voluntary, come to be performed more or less unconsciously, they are styled *mechanical*. A thousand instances of them might be given; *all voluntary* ones becoming more or less so by *habit*. The nervous paths through which the mandates of the will pass to the muscles grow more accessible and open by use; and less and less effort of volition becomes necessary to thread them, every time that effort is made. In the early periods

of life the will is exercised in tutoring its corporeal instruments to give prompt and ready obedience to its commands; every day new lessons are acquired, and old ones confirmed; and, having at length a practised body at its beck, it is able to execute numerous and complicated movements with as much precision as those of the most delicate and subtile kind, and all, or any of them, without being itself distracted with the business of their immediate supervision. Like the general of a disciplined army, the will issues mandates of action or control; but is not cognizant, without a special effort of attention, of anything beyond the general result of the various movements that its orders produce. And the body, that executes them, is constantly performing other movements, of a routine nature, connected with its safety, comforts, or ordinary functions; which, though at first they had demanded the general's attention, and might again attract it, yet having been learnt by drilling, are now executed without his anxiety or even co-operation. They are the working of a practised organization. Thus many particular movements are included in general ones, without the will having the smallest immediate share in their production. The countenance takes its expression from the prevailing action of its muscles, often in spite of our efforts to the contrary; and, in general, the attitude and bearing wear a corresponding character. And thus several general movements, which naturally (or by an act of the untutored will) are impossible because incompatible, are rendered capable of being simultaneously performed.

The following works may be consulted in reference to Muscle and Muscular Action:—Prochaska, de carne musculari; 1778: Fontana, sur le venin de la vipère; 1781: John Hunter's Croonian Lectures, works by Palmer, vol. iv.; Blane, on Muscular Motion, in his select dissertations; the various works on General Anatomy quoted in former chapters; Barclay on Muscular Motion; Mayo's Physiology; Müller's Physiology, by Baly; the Articles Muscle and Muscular Action, in the Cyclop. Anat. and Phys. For greater details on the Motions and Attitudes of the body than would be consistent with the plan of this work, we refer to the Article Motion in the Cyclop. Anat. and Phys.; and to Weber's Mechanik der Menschlichen Gehewerkzeuge.

CHAPTER VIII.

INNERVATION.—EXAMPLES OF NERVOUS ACTIONS.—NERVOUS MATTER, ITS CHEMICAL AND ANATOMICAL ANALYSIS.—THE FIBROUS AND VESICULAR NERVOUS MATTER.—THE NERVOUS SYSTEM.—THE NERVES, CEREBRO-SPINAL AND SYMPATHETIC.—THE NERVOUS CENTRES.—NERVES AND NERVOUS CENTRES IN INVERTEBRATA.—DEVELOPMENT AND REPRODUCTION OF NERVES.

The function of innervation is effected through the medium of the nervous system, which, ramified throughout the body, and connected with and passing between its various organs, serves them as a bond of union with each other, as well as with the sentient principle of the

animal. The mind of man influences his corporeal organs through the instrumentality of this system, as when volition or emotion excites them to action; and, on the other hand, certain changes in the organs or textures of the body may affect the mind through the same channel, as when impressions made upon them excite mental perceptions. In this way the nervous system becomes the main agent of what has been called the life of relation; for without some channel for the transmission of the mandates of the will to the organs of motion, or some provision for the reception of those impressions which external objects are capable of exciting, the mind, thus completely isolated, could hold no communion with the external world.

The nervous system, however, can act independently of mental influence. A material or physical change in the nervous substance, unconnected with any affection of the mind, is capable of exciting the action of nerves, and consequently of those organs which are subject to their influence. Some kind of molecular change in the nervous matter is all that is at any time required for the development of its peculiar power; and it is as easy to conceive that this alteration may result from some organic cause, as from mental influence. Of this kind, no doubt, are all those nervous actions with which are associated the functions of the life of the individuals, or, in the language of Bichat, of organic life; an essential character of which is, that they are completely removed from the influence of the will.

In every ordinary voluntary action, the first step is a mental change, in which consists the act of volition. The mind is perfectly able to induce this change in itself, without any reference to the body: but if it direct its influence upon certain muscles, the contraction of those muscles immediately ensues, in a combined and regular manner, so as to produce the predetermined voluntary action. But the influence of the mind cannot be brought to bear upon the muscles, save through the intervention of the nerves, as is amply proved by the destruction of certain voluntary movements, which is consequent upon the destruction of certain nerves.

Again, in all cases of common or of special sensation, that state of the mind, in which the sensation consists, is induced by an impression made upon certain bodily organs, and conveyed to the mind through the instrumentality of the nerves. For there is abundant evidence to prove, that, while the mind is of itself capable of entering that state, it cannot do so in obedience to bodily change, if certain nerves be destroyed or impaired; that, in short, the nerves are the only corporeal channel through which sensations can be excited. If the skin be forcibly irritated or compressed, instantly pain is felt; but, were the nerves of the skin destroyed, no degree of irritation or pressure would make the mind cognizant of the injury. Light is admitted to the eye, and forthwith a corresponding affection of the mind ensues; but, for the production of this, the integrity of the optic nerve is a necessary condition.

In these examples of nervous action, it will be observed that, in the former instance, mental change produces bodily action; and, in the latter, an impression upon some part of the body precedes and

gives rise to an affection of the mind. In both cases nervous power is called forth: in the one, it acts in the direction from mind to body; in the other, from body to mind. In both cases, destruction of the nervous matter would prevent the development of the force. The muscles may be sound, and the will may be vigorous; but without perfect nerves the latter cannot impart its mandates to the former. Or the eye may be perfect in all its optical adjustments, and the mental sensibilities keen and quick; and yet, if the optic nerve be diseased, the light which falls upon the retina produces no impression upon the mind.

"Of the nature of the connection of this great sensorial organ," (the nervous system,) says Dr. Brown, "with the sentient mind, we never shall be able to understand more than is involved in the simple fact, that a certain affection of the nervous system precedes immediately a certain affection of the mind. But though we are accustomed to regard this species of succession of bodily and mental changes as peculiarly inexplicable, from the very different nature of the substances which are reciprocally affected, it is truly not more so than any other case of succession of events, where the phenomena occur in substances that are not different in their properties, but analogous, or even absolutely similar; since, in no one instance of this kind, can we perceive more than the uniform order of the succession itself; and of changes, the successions of which are all absolutely inexplicable, none can be said to be more or less so than another. That a peculiar state of the mere particles of the brain should be followed by a change of state of the sentient mind, is truly wonderful; but, if we consider it strictly, we shall find it to be by no means more wonderful than that the arrival of the moon at a certain point of the heavens should render the state of a body on the surface of our earth different from what it otherwise would naturally be; or that the state of every particle of our globe, in its relative tendencies of gravitation, should be instantly changed, as it unquestionably would be, by the destruction of the most distant satellite of the most distant planet of our system, or, probably too, by the destruction even of one of those remotest of stars which are illuminating their own systems of planets, so far in the depth of infinity that their light—to borrow a well-known illustration of sidereal distance—may never yet have reached our earth since the moment at which they darted forth their first beams on the creation of the universe. We believe, indeed, with as much confidence, that one event will uniformly have for its consequent another event, which we have observed to follow it, as we believe the simple fact, that it has preceded it in the particular case observed. But the knowledge of the present sequence, as a mere fact to be remembered, and the expectation of future similar sequences, as the result of an original law of our belief, are precisely of the same kind, whether the sequence of changes be in mind or in matter, singly, or reciprocally in both." (*Philosophy of the Human Mind.* Lect. xix.)

It is not merely through voluntary effort that the mind can excite the action of nerves. The involuntary, and often uncontrollable, in-

fluence of emotion is likewise able to give rise to certain movements, and even to produce certain sensations, through the nerves. How quickly the expression of the countenance changes under the varying phases of mental emotion; and how faithfully does it naturally portray the working of the mind within! And fear, joy, disgust, horror, are each accompanied with sensations so peculiar, as to leave an indelible impression on the minds of those who have once experienced them.

There are many actions of the living frame, however, in which the play of the nervous system is unconnected with mental change, which are therefore wholly physical, in origin, as well as in nature. The movement of the œsophagus in propelling food onwards to the stomach is dependent mainly, if not solely, upon the physical stimulus of the food acting upon the nerves of the organ, which in their turn provoke its muscular fibres to contract. The slightest touch, even of a feather, to the mucous membrane of the fauces causes the muscles of deglutition to contract forcibly, as in the act of swallowing; nor can the will control or prevent their action. When the edge of the eyelid is touched, the orbicular muscle contracts forcibly, and in immediate response to the stimulus applied. When light is suddenly admitted to the eye, the pupil may be observed to contract to a degree proportionate to the intensity of the stimulus. Of this action of the iris the individual is quite unconscious, although perfectly sensible of the admission of light to the eye; nor can he, by any direct influence of volition, modify or oppose it.

We remark, in reference to these actions, that the mind has no share in their production. In some of them, indeed, it is conscious of the application of the stimulus, as well as of the muscular act which follows. But no effort of the will, however great, could interrupt the uniform and natural sequence of the phenomena. And it is well known to medical men that actions of this kind may take place in coma, when all mental manifestations are completely in abeyance.

These facts afford abundant evidence of a class of nervous actions, which, in respect of their exciting cause, as well as in their intrinsic nature, are independent of mental influence, and which ought on this account to be distinguished from those of volition, sensation and emotion. Their mechanism is more complex than that of the mental nervous actions; for, while in the latter the change in the nerves is propagated in only one direction, in the former it passes first to some central part of the nervous system, and thence it travels in an opposite course to the motor organs. Hence two nerves are necessary for such actions; the one as an excitor, the other as a motor nerve; and, on this account, Dr. Marshall Hall has distinguished these actions by the name of *excito-motory*.

That a physical change may excite nervous action quite independently of mental influence, is further proved by instances of convulsive movements, more or less violent, which are produced by a morbid irritation of the brain or spinal cord.

The peculiar animal matter, through the agency of which all these

ar than the other, and is simply the propagator of impressions upon it.

en these two kinds of nervous matter are united together in a f variable shape or size, the body so formed is called a *nervous* and the threads of fibrous matter which pass to or from it are *nerves*. The latter are *internuncial* in their office; they estab- communication between the nervous centres and the various f the body, and *vice versa*; they conduct the impulses of the s to the periphery, and communicate the impressions made upon ripheral nervous ramifications to the centres. The centres are the ources of nervous power, the laboratories in which the nervous s generated: the mind is more immediately connected with one a, the brain, which, on that account, possesses greater physical pment and acquires pre-eminence over the others. The smaller s centres are called *ganglions;* the larger ones are the *brain inal cord.* All of these are found in the human subject, and in rtebrate animals. In the invertebrate classes, the centres are a variously disposed, according to the shape and actions of the s.

brain and spinal cord, and the system of nerves connected with constitute the *cerebro-spinal* portion of the nervous system, Bichat distinguished as the nervous system of *animal life.* rves of the senses, and those of volition and common sensation, nnected with it, as well as those which are concerned in many e purely physical nervous actions with which the mind has no ction. There are very numerous ganglions connected with this which are conveniently comprehended under the same title. are, the ganglions on the posterior roots of the spinal nerves, nglion of the fifth pair, those of the glosso-pharyngeal and of the

remainder of the nervous system is made up entirely of gan- , with their connecting cords and nerves, which ramify in a

as independent of that system, is a question which must be reserved for future examination. This is the *sympathetic* or *ganglionic system*, formerly known and described as the *great intercostal nerve*, and by Bichat as *the nervous system of organic life*: it has also been called *the visceral nerve*. All these titles are liable to objection, inasmuch as each involves to a greater or less extent some theory of the uses or actions of these nerves; but the two first-mentioned are preferable, as those which are best known, and most confirmed by use.

The nervous system, then, in man and the vertebrate series, consists of the brain, spinal cord, and the nerves associated therewith, the *cerebro-spinal system;* and that double chain of ganglia, with their nerves, situate along the spinal column, the *sympathetic* or *ganglionic system.* Among the invertebrata, although the arrangement of the nervous system differs very materially from that in the vertebrata, an analogous subdivision of it may be made in a large proportion of those classes, the anatomy of which has been satisfactorily made out.

Physical and Chemical properties of the Nervous Matter.—The nervous matter of both kinds is a soft, unctuous substance, easily disturbed by slight mechanical force. Were it not associated with other tissues, and supported, to a certain extent, by the blood-vessels which ramify among its elements, its physical tenacity would be very feeble.

Its great softness is due, in part, to the admixture of a large quantity of water with it, which constitutes three-fourths, or four-fifths, and, in many instances, seven-eighths, of its weight. According to Vauquelin, whose analysis was made in 1812, the brain is an emulsive mixture of albumen, fatty matter, and water; the last holding in solution certain saline and other ingredients common to the brain with other parts of the body. By solution in boiling alcohol, Vauquelin was enabled to resolve the fatty matter into elaine and stearine (margarine ?) The following table gives the result of his analysis:

Albumen			7·00
Cerebral fat	Stearine	4·53	5·23
	Elaine	0·70	
Phosphorus			1·50
Osmazome			1·12
Acids, Salts, Sulphur			5·15
Water			80·00
			100·00

Vauquelin remarked that the medulla oblongata, and medulla spinalis, have the same composition as the brain, but contain a much larger proportion of cerebral fat, with less albumen, osmazome, and water.

These results are confirmed, in the main, by the analysis of Fremy, which was published in the Annales de Chimie for 1841. M. Fremy states, that the three principal constituents previously detected by Vauquelin, exist in the following proportions in one hundred parts: seven parts of albumen, five parts of fatty matter, and eight parts of water.

From the fatty matter of the brain M. Fremy extracts various secondary organic compounds; namely, 1. Cerebric acid; a white

ıbstance in the form of crystaline grains, abounding in carbon, and ›ntaining a minute proportion of phosphorus. 2. Cholesterine, the ıme as that which is obtained from bile. In preparations of the ·ain preserved in spirits, a substance of crystaline character resemıing cholesterine is apt to form round the piece. 3. Oleophosphoric :id; a peculiar fatty acid, containing from 1·9 to 2 per cent. of phosıorus in the condition of phosphoric acid. Fremy regards it as ıalogous to the compound of sulphuric acid and elaine, or sulphleic acid. 4. Traces of elaine, margarine, and fatty acids. These rinciples do not always exist in an isolated state; for the cerebric cid is often combined with soda, or phosphate of lime, and the oleo›hosphoric acid is commonly found in union with soda.

The quantity of phosphorus which may be found in the nervous matter varies considerably at different periods of life, and is very small in idiotcy. According to L'Heritié's analyses, the *minimum* of this element is found in infancy, in old.age, and in idiotcy; and the *maximum* of water exists in the infant. The following is a table of his comparative analyses:

	Infants.	Youth.	Adults.	Old Men.	Idiots.
Albumen	7·00	10·20	9·40	8.65	8·40
Cerebral fat	3·45	5·30	6·10	4·32	5·00
Phosphorus	0·80	1·65	1·80	1·00	0·85
Osmazome and Salts	5·96	8·59	10·19	12·18	14·82
Water	82·79	74·26	72·51	73·85	70·93
	100·00	100·00	100·00	100·00	100·00

A careful comparative analysis of the vesicular and fibrous matter is as yet a desideratum. We are ignorant of the nature of the coloring material of the former. John states that the vesicular substance is deficient in white fatty matter, and that its albumen is less tenacious than that of the fibrous substance.

Of the fibrous nervous matter.—Of the two kinds of nervous matter, the fibrous is that which is most extensively diffused throughout the body. It not only forms a large portion of the nervous centres, either alone or mixed with vesicular matter, but it is the principal constituent of the infinite multitude of nerves which connect them with the various tissues and organs.

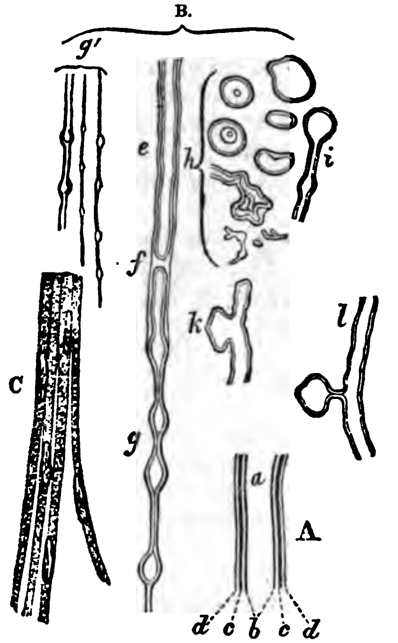
The structure of the fibrous matter should be examined in a piece of nerve, and in a thin section from the white part of a nervous :entre, as the brain or spinal cord. These should be torn with neeıles, so as to separate and isolate as much as possible the elementary ıarts, and to remove, as far as may be practicable, extraneous tissues.

The fibrous nervous matter, wherever it is found, consists of fibres ·hich have a definite arrangement. Two kinds of primitive fibre re present in the nervous system, and these we shall distinguish ; the *tubular* fibre, or the *nerve-tube*, and the *gelatinous* fibre. The ›rmer are infinitely the more numerous; the latter being found hiefly in the sympathetic system.

1. *Of the tubular fibre.*—When a nerve-tube is perfectly recent, ıd unaffected by reagents, it presents, if viewed by reflected light, beautiful pearly lustre, and appears to be quite homogeneous. But

if viewed by transmitted light, and with a sufficient magnifying power, a more complicated structure becomes visible in all the largest and best marked specimens (fig 52, A, B, and fig. 53, *a*). Most externally is the *tubular membrane* (A, *d d*), an homogeneous and probably elastic tissue of extreme delicacy, analogous to the sarcolemma of striped muscle (p. 150), and according to our observation, not presenting any such distinct, longitudinal, or oblique fibres in its composition as have been described by some writers. Within the edge of the tubular membrane, on each side, are seen two thicker and darker lines (A, *c*, *c*, *b*), which appear to mark the outer and inner limits of an inner layer of different composition and refracting power, and which is generally known as the *white substance of Schwann*. This forms a tube within the tubular membrane. Within the white substance of Schwann is a transparent material, occupying the axis of the nerve-tube (A, *a*). This has been called by Remak the *flattened band;* but a better name for it is that of *axis cylinder*, employed by Rosenthal and Purkinje.

Fig. 52.



A. Diagram of tubular fibre of a spinal nerve:—*a.* Axis cylinder. *b.* Inner border of white substance. *c c.* Outer border of white substance. *d*, *d.* Tubular membrane. B. Tubular fibres; *e*, in a natural state, showing the parts as in A. *f.* The white substance and axis cylinder interrupted by pressure, while the tubular membrane remains. *g.* The same, with varicosities. *h.* Various appearances of the white substance and axis cylinder forced out of the tubular membrane by pressure. *i.* Broken end of a tubular fibre, with the white substance closed over it. *k.* Lateral bulging of white substance and axis cylinder from pressure. *l.* The same more complete. *g'.* Varicose fibres of various sizes, from the cerebellum. C. Gelatinous fibres from the solar plexus, treated with acetic acid to exhibit their cell-nuclei. B and C magnified 320 diameters.

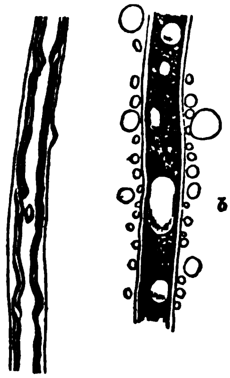
It is evident, that the whole of the matter contained in the tubular membrane is extremely soft, for it is found to yield under very slight pressure, and may be readily made to pass from one part of the tube to another. When pressed out (B. *h* to *l*), it is apt to assume more or less the appearance and form of globules, which retain the same characters of outline which they possessed in the nerve-tube; that is, they have a transparent interior, bounded by a layer of the white substance of Schwann, marked by its double contour. It would appear that the latter structure is particularly apt to form a coating or film over the central material, and thus to isolate it from surrounding tissues. This tendency may be understood by a reference to fig. 52, *h* to *l*.

When the nerve-tube is placed in ether, the white substance is in part immediately dissolved, and a number of oil-like globules appear

within and without the tubular membrane (fig. 53, *b*). Proba- s margarine is dissolved, and the elaine set free in the form of bules. The interior of the tube is endered decidedly granular. In water hite substance of Schwann remains olved, while the interior of the fibre uently, though not always, rendered lar.

e tubular membrane presents the same l characters wherever it is met with. e white substance of Schwann exhibits variety as regards its thickness in dif- parts of the nervous system. In the s it is more developed than in the cen- but even in the former it differs a good s to thickness. We find it most de- ed in the ordinary spinal nerves; in of pure sense it exists in small quan- Both these elements of the tubular evidently afford mechanical protection substance which forms its axis; but less one or both of them may have a r physiological office, insulating the and keeping it distinct from any in- nce with constituents of neighboring The chemical composition of the substance, being obviously different hat of the axis, sufficiently denotes a nce of function in these two portions of the nerve-tube. The ylinder of the nerve-tube, though in general soft and pulpy, is e instances of firm texture, and when broken projects beyond ite substance (fig. 56, *c*). It then occasionally exhibits a well- d fibrous character, and may even split into filaments.

Fig. 53.



Nerve-tubes of the common eel:—*a*. In *water*. The delicate line on its exterior indicates the tubular membrane. The dark, double-edged inner one is the white substance of Schwann, slightly wrinkled. *b*. The same in *ether*. Several oil-globules have coalesced in the interior, and others have accumulated around the exterior of the tube. The white substance has in part disappeared.—Magnified 300 diameters.

en the tubes are quite fresh, and have been but little disturbed nipulation, their form is that of a perfect cylinder. Pressure, aration, is apt to alter their shape by disturbing the position of ntained pulp, pushing more than is natural into some parts of be, and consequently diminishing the bulk of the contents in the nt parts; so that the latter collapse, whilst the former become led, enlarged, and even varicose (fig. 52, B). Nerve-tubes, ve been thus affected, sometimes present merely a slight wavi- f one or both margins, but more frequently a series of distinct ngs or varicosities separated by constricted portions. These ngs are found at very irregular distances from each other, and xtremely in shape and size. They are much more apt to form some nerve-tubes than upon others; and this is apparently to a feebleness of the tubular membrane, and perhaps, also, to degree of consistence of the contained nervous pulp. In the of special sensation the tubes are very delicate in structure, ry apt to exhibit this change; and in the fibres of the brain

and spinal cord the same tendency is observable. It was formerly supposed by Ehrenberg, that these varicosities were natural, and existed during life; and that they afforded a valuable morphological character of the nerves of pure sense, and of the cerebro-spinal centre. Many circumstances, however, oppose this view: thus, the irregularities in the shape, size, and number of the varicosities appear very unlike a natural disposition: in a piece of the brain or spinal cord which has not been much pressed or torn, the nerve-tubes often exhibit a cylindrical figure, and even in the manipulated specimen the varicose tubes form only a portion. In some nerves, such as those of muscles, the tubes, although not prone to become varicose, may be made so by firm pressure and violence in manipulation; and in the nerve-tubes of young animals, the tissues of which are more tender, and contain more abundant water, this change is particularly apt to take place.

The nerve-tubes, for the most part, lie parallel to each other, always without branching, and if we except their terminal looping in other textures, without any inosculation. This very interesting and important feature in the anatomy of the nerve-tubes was recognized long ago by Fontana, and has been confirmed by nearly every subsequent observer. It may be seen in the nervous centres, as well as in the nerves themselves. In the latter it may be well demonstrated by examining a piece of nerve on a dark ground *as* an opaque object. The primitive fibres, viewed in this way, appear as so many transparent tubes, containing an exquisitely delicate, soft, pearly-white material. The tubular fibres vary in diameter, from $\frac{1}{1000}$ to even $\frac{1}{10000}$ of an inch; but their average width is from $\frac{1}{2000}$ to $\frac{1}{4000}$ of an inch.

2. *Of the gelatinous nerve-fibre.*—This term is applied by Henle to certain fibres found principally in the sympathetic nerve. They are flattened, soft, and homogeneous in appearance; containing numerous cell-nuclei, some of which are round, others oval; some situated in the centre of the fibre, others adhering to either edge; their longest diameter being generally parallel to the longitudinal axis of the nerve. These nuclei are arranged at nearly equal distances, and frequently exhibit distinct nucleoli (fig. 52, c). Sometimes these fibres show a disposition to split into very delicate fibrillæ. Acetic acid dissolves the fibre, leaving the nuclei unchanged. These fibres, containing nothing analogous to the white substance of Schwann, are devoid of that whiteness which characterizes the tubular fibre; and it would seem that the gray color of certain nerves depends chiefly upon the presence of a large proportion of the gelatinous fibres. Hence they are sometimes called *gray fibres.*

The mode or connection of the gelatinous fibres with the elements of the nervous centres, is, as yet, quite unknown. They are found, in considerable numbers, in what are called the roots of the sympathetic, or the communications of that nerve with the spinal nerves: it has been supposed by Valentin that they are continuous with certain elements of the vesicular nervous matter.

These fibres are smaller, in general, than the tubular fibres; their

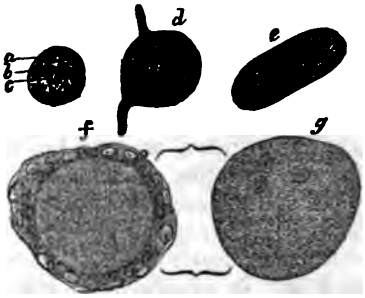
r ranges between the $\frac{1}{6000}$ and the $\frac{1}{4000}$ of an inch. They e very much the fibres of unstriped muscle.

e vesicular nervous matter.—This is distinguished by its dark gray color, and soft consistence: it is found in the nervous but never in nerves, probably so called, and it is always l by a considerable plexus of blood-vessels.

essential elements of the rvous matter are *vesicles* , containing nuclei and . They have been also *erve* or *ganglion globules*. ll of each vesicle consists ceedingly delicate mem- containing a soft but te- finely granular mass. *:leus* of the cell is gene- entric, much smaller than taining vesicle, and adhe- some part of its interior. ıcture is apparently the that of the outer vesicle. *cleolus* is a minute, re- ly clear and brilliant also vesicular, inclosed the nucleus. It forms a haracteristic and nspicuous part of re-vesicle.

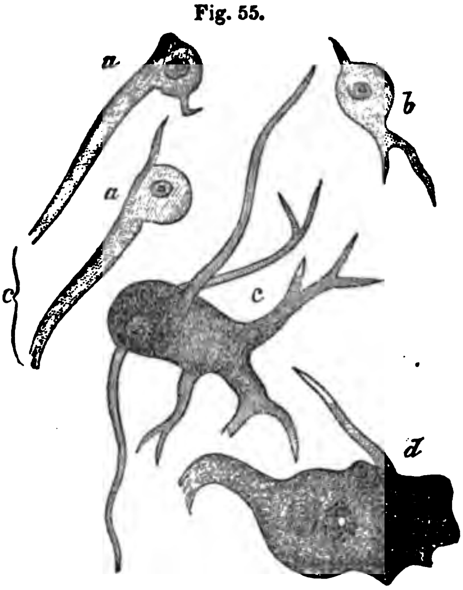
ordinary or pre- form of these ele- s that of a globu- cle. So soft and ssible are they, r, that a good diversity of shape ifest in them, by of the compres- ey suffer as they cked together *in* Hence some are al, others ovoidal, soidal. In some s we find, external nucleus, particles ırser kind, which cumulated in a frequently of a ıar form. These gment granules; resence gives a olor to a portion

Fig. 54.



Nerve-vesicles from the Gasserian ganglion of the human subject:—*a* A globular one with defined border; *b*. its nucleus; *c*. its nucleolus. *d*. Caudate vesicle. *e*. Elongated vesicle, with two groups of pigment particles. *f*. Vesicle surrounded by its sheath, or capsule, of nucleated particles. *g*. The same, the sheath only being in focus.—Magnified 300 diameters.

Fig. 55.

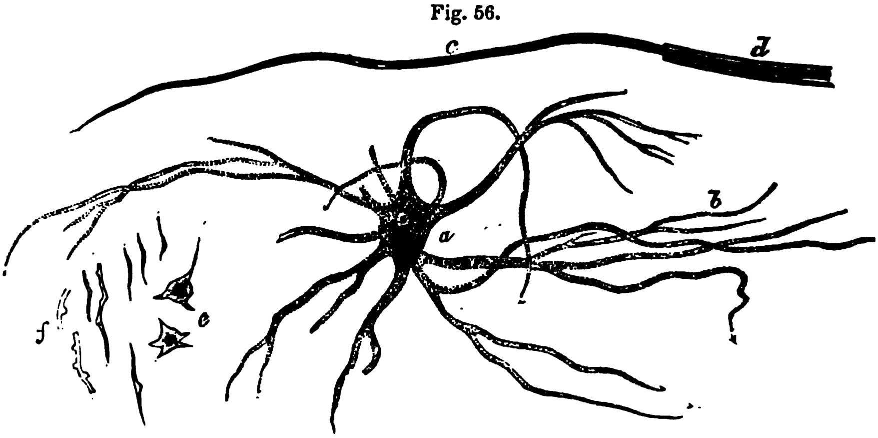


Ganglion globules, with their processes, nuclei, and nucleoli:—*a*. *a*. From the deeper part of the gray matter of the convolutions of the cerebellum. The larger processes are directed towards the surface of the organ. *b*. Another from the cerebellum. *c*. *d* Others from the post. horn of gray matter of the dorsal region of the cord. These contain pigment, which surrounds the nucleus in *c*. In all these specimens the processes are more or less broken.—Magnified 200 diameters.

of the vesicle. Sometimes we find two groups of pigment granules in one vesicle. They are usually of a reddish, or yellowish-brown color.

Another form of nerve-vesicle is characterized by one or more tail-like processes extended from it, and to such nerve-vesicles we may apply the term *caudate*. They possess the nucleus and nucleolus, as in the more simple form; and contain one or more masses of pigment, which are often of very considerable size. Both the vesicles and their caudate processes vary greatly in size and shape. The largest nerve-vesicles are found among those of this kind. Sometimes there is but a single process from this vesicle; or there may be two, proceeding from opposite sides; or there may be several, extending in various directions. There is great difference in the shape of these caudate vesicles, as may be observed in figs. 55 and 56, where different varieties of them are represented. In point of structure, the caudate processes are exceedingly delicate, and finely granular, like the interior of the vesicle, with which they distinctly seem to be continuous. Such is the delicacy of these processes, that they readily break off; in general, very close to the vesicle. Sometimes, however, one or more of them may be traced to a considerable distance, and will be found to divide into two or into three branches, which undergo a further subdivision, and give off some extremely fine transparent fibres (fig. 56, *b*), the connection of which with the other elements of the nervous tissue has yet to be ascertained. It is most probable, however, that they either serve to connect distant vesicles, or else that they become continuous with the axis cylinders of the tubular fibres. In the cerebro-spinal centre, we have found the tissue in the vicinity of the caudate vesicles freely traversed in all direc-

Fig. 56.

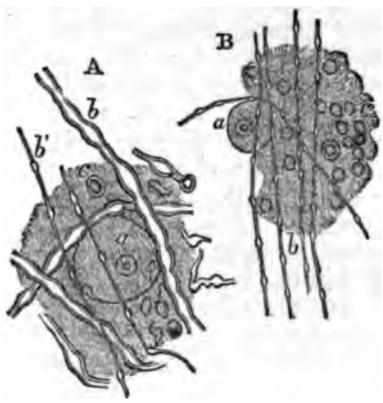


a. A large caudate nerve-vesicle, with diverging and branching processes, some of which, *b*, are seen to pass off into extremely minute filaments. These seem to bear a very close resemblance to the central part of a tubular fibre, *c*, which is prolonged some way beyond the broken edge of its tubular membrane and white substance, *d*. At *e*, are some small nerve-vesicles, stellate in form, doubtless from numerous processes given off from them: *f*, several extremely small nerve-tubes, some of which are varicose. This figure exhibits the great variety of size of the vesicles and tubes. *a*. is from the posterior horn of the gray matter of the spinal marrow, and is magnified only 120 diameters, while the vesicles and tubes at *e*, from the gray matter of the lower end of the cord, are magnified 300 diameters. *d*. is also from the spinal marrow, and is magnified 200 diameters.

by numerous very delicate filaments, which seem to be the rami-ons of the caudate processes. These often exhibit considerable ity and elasticity. The situations from which we may obtain caudate vesicles as are best suited for examination are the *locus* in the crus cerebri, and the gray matter of the cerebellum and l cord.

e nerve-vesicles do not lie in immediate contact with each other. are either imbedded in a soft, granular matrix, as in the brain, iveloped in a capsule of ated cells, as in the gan- fig. 54, *f*, *g*). The inti- connection of this granular h to the vesicle, and to its sses when they exist, in- es greatly the difficulty of ining them. It is not easy tach them from this invest- . This is generally effected cident more than by skill nipulation, and it is along roken margin of the piece r examination that we shall ed in detecting the most ct vesicles.

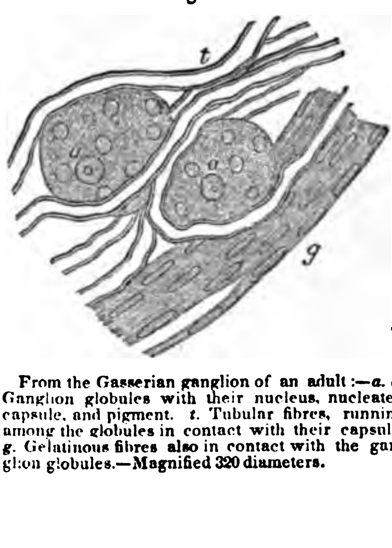
Fig. 57.



A. Blending of the vesicular and fibrous nervous matter in the dentate body of the cerebellum:—*a*. Ganglion globule, with its nucleus and nucleolus. *b*. Nerve-tube, slightly varicose, in close contact with the ganglion globule. *b'*. Smaller nerve-tubes. These parts all lie in a finely granular matrix in terspersed with nuclei, *c*. B. Vesicular and fibrous matter of the laminæ of the cerebellum. *a*. Ganglion globule. *b*. Very minute nerve-tubes traversing a finely granular matrix, in which are numerous rounded nuclei, *c*.

most situations where ular matter is found in the ous centres, tubular fibres nall though variable size le with its elements in er or less number, and in places both varieties of are found (figs. 57 & 58). etermine the precise con- on which these respective entary parts form with each is a problem of the deep- nterest. No more, how- , can be said respecting it esent, than that the relation rve-fibres to nerve-vesicles e centres is most intimate, that the latter are rarely with without one or more of ormer in immediate connec- with them.

Fig. 58.



From the Gasserian ganglion of an adult:—*a*. *a*. Ganglion globules with their nucleus, nucleated capsule, and pigment. *t*. Tubular fibres, running among the globules in contact with their capsule. *g*. Gelatinous fibres also in contact with the ganglion globules.—Magnified 320 diameters.

aving premised this general unt of the anatomical ele- s of the two kinds of nerv- matter, we may now con- separately the two leading

subdivisions of the nervous system; namely, the nerves and the centres.

Of nerves.—A bundle of nerve-fibres, surrounded and connected by areolar tissue, constitutes a nerve.

The nerves of the cerebro-spinal system differ in several important particulars from those of the sympathetic, and they should, therefore, be examined separately.

Of the cerebro-spinal nerves.—The areolar tissue which invests the nerve-fibres is called *the neurilemma.* It is analogous to the sheath of the same membrane which surrounds the elementary fibre of striped muscle. From its deep surface the layers of areolar tissue pass, forming so many partitions between the smaller bundles, or the individual fibres, of which the nervous trunk is composed. The office of this structure is evidently to give protection to the delicate nerve-tubes, and to support the plexus of minute capillary vessels from which they derive their nutriment.

The neurilemma is composed of fibres of white fibrous tissue, and presents to the naked eye the silvery aspect of that texture. Some persistent cell-nuclei are scattered throughout it. That portion of it which forms the partition between the fibres contains a little yellow fibrous tissue of the finest description.

The *blood-vessels* are distributed upon the external investing sheath, and upon the septa. They are disposed similarly to those of muscles, and run parallel to the fibres of the nerve. The capillaries are among the smallest in the body: they form oblong meshes of considerable length, completed at long intervals by vessels which cross the fibres of the nerve more or less transversely. These blood-vessels are generally derived from neighboring arterial branches; sometimes a special vessel accompanies a nervous trunk, and even perforates it, passing along its axis, as in the great sciatic and the optic nerves.

The composition of a cerebro-spinal nerve may be shown by removing the neurilemma, and separating the fibres by needles. These fibres are chiefly of the tubular kind. In diameter they vary considerably, but do not exceed the $\frac{1}{1300}$ of an inch in man and the mammalia. They lie within the sheath in simple juxtaposition, and parallel to each other; excepting where a branch is about to separate, when a bundle of nerve-tubes gradually deviates from its previous course, and forms a very acute angle with the trunk, still, however, preserving the parallelism of its constituent fibres.

Nerves are said to *arise* or have their *origin* in the nervous centre to which they are on the one hand attached, and to *terminate* or *be distributed* among the elements of the various textures on the other hand. It is best to continue the use of so definite and simple a meaning to these terms. Attempts to alter their signification in accordance with opinions of the functions of the constituent fibres can at present do little but confuse descriptions. We call a nerve *cerebral* or *encephalic*, if it be connected at its origin with some part of the nervous mass within the cranium; and *spinal*, if its apparent origin be from the spinal cord.

Origin.—The fibres of nerves may be traced into the nervous cen-

es, the white or fibrous part of which they contribute to form. As ey enter the centre, the fibres diverge slightly either singly or in parate bundles, and pass on to form a connection with vesicular atter, in the immediate vicinity of the point of immergence or at a ore remote situation. How the fibres comport themselves with re- ect to the elements of the vesicular matter is not exactly known. It certain, however, that nerve-tubes frequently adhere to the sheaths f nerve-vesicles, and that many of them pass between the nerve- esicles, probably to form a connection with more distant ones. This ay be well seen in the vesicular matter of any of the centres. It very distinct in the ganglions, and also sufficiently manifest in the inal cord or brain. In the last-named centres some of the tubes hich are found in the vesicular matter are reduced to an extremely inute size (figs. 56, *f*; 57, A, *b'* and B, *b*), and exhibit small vari- osities, sometimes at very regular distances from each other.

Valentin describes a looped and plexiform arrangement of the fibres the vesicular matter of the centres. Hitherto, such an arrange- ent has eluded our observation so completely, that, but for the igh authority on which this statement rests, we should not have eemed it necessary to allude to it. The only confirmation of this iew with which we have met is derived from an highly interesting issection, by Mr. Lonsdale of Edinburgh, of a monstrosity, in which e spinal cord, medulla oblongata, and cerebellum were absent, but e hemispheres of the brain were present. Several of the encepha- c and spinal nerves hung "as loose threads" in the cavity of the anium or spine. On examining the free or central extremities of ese nerves, their constituent fibres were found to form distinct loops, nvex towards the cranial or spinal cavity. These loops were im- edded in granular matter, supposed to be vesicular matter in an rly stage of formation. Similar loops were observed by the same atomist in the cranial nerves of an anencephalous fœtus which had een preserved in spirits.*

Branching.—As a nerve passes from centre to periphery, it breaks p into a number of small bundles, which form so many branches estined for the organs or tissues among which they are placed. hese branches generally separate from the parent trunk at an acute gle, and soon plunge into the muscles or other parts to which they nd, dividing and subdividing among them. Some exceptions to is rule, however, are occasionally met with, in which the branch rms a right or an obtuse angle with the trunk.

Before a branch separates, the parent nerve seems wider for some istance above the point of visible separation. This is owing to a ivergence of the fibres within the trunk before they actually leave it, d not to any increase in the number of the nervous elements. A od example may be seen in the auricular nerve of the neck, as it inds upwards over the sterno-mastoid muscle.

Anastomosis.—In their branchings nerves subdivide, not only to ass immediately to their distribution in muscles or other parts, but

* Dr. Lonsdale's case of Monstrosity. Ed. Med. and Surg. Journ., No. 157.

also to form a connection, by some of their filaments, with other nerves, and to follow the course of the latter, whether to the periphery, or back again to the centre, instead of passing to the destination of the primary trunk. By these means nervous filaments connected with very different parts of the brain and spinal cord become bound together in the same neurilemma, and a nerve is formed compounded of nerve-tubes possessing different functions. The *anastomosis* of nerves thus formed differs from the more correctly named anastomosis of blood-vessels; for in the latter case the canals of the anastomosing vessels communicate, and their contents are mingled; but in the former the nerve-tubes simply lie in juxtaposition, without any coalescence of their walls, or any admixture of the material contained within them.

The simplest kind of anastomosis is that which occurs in almost every spinal nerve. The anterior and the posterior roots of these nerves, emerging from different parts of the spinal cord, and possessing, as is now proved, very different endowments, are united after passing through the dura mater, and are bound together as one nerve; the respective tubules being so completely intermixed that the ramifications, which pass off in the subsequent course of the nerve, for the most part contain tubules from both roots, and therefore possess the functions of both.

Fig. 59.

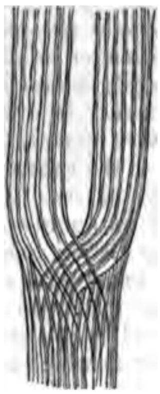


Diagram to show the decussation of the fibres within the trunk of a nerve.—(After Valentin.)

And even in a nervous trunk, thus formed, there is an interchange of place between the component filaments, so that those which were at first on the surface of the nerve pass into its centre, and are replaced by others which had been deep-seated; a decussation of the fibres occurring as they change places (fig. 59). Hence it is often difficult to follow a bundle for any distance in a nervous trunk. According to Kronenberg, this kind of interchange is more frequent in some nerves than in others; and it is stated by this author that in the external cutaneous nerve of the arm he found some bundles, which passed through a distance of six inches without uniting with neighbouring ones.

By another form of anastomosis nervous loops or arches are formed, the convexities of which are directed towards the periphery, and give off filaments to the neighbouring parts. The well-known anastomosis between the ninth or hypoglossal nerve, and the cervical plexus, in front of the carotid artery, may be quoted as a good example. Certain fibres, which come from the medulla oblongata as part of the ninth nerve, leave that nerve as it crosses over the carotid artery, pass down in front of the artery, and apply themselves to a descending branch of the cervical plexus, forming in front of the carotid artery and jugular vein an arch with the concavity directed upwards, several nerves passing from the convexity to neighbouring muscles. Some of the filaments which are given off from this arch, are derived from

ie ninth nerve, and others from the cervical plexus; whilst others eem to form a complete arch, and to be equally connected with both erves; and, if we trace these latter fibres from the ninth nerve, re find them passing upwards and backwards into the descending ranch of the cervical plexus, and so returning to the spinal cord. The nervous loop, thus formed, must evidently establish a communiation between the cervical region of the spinal cord and that portion f the medulla oblongata whence the ninth nerve appears to derive ts origin.

Similar nervous loops, leaving the nervous centre as a constituent f one nerve, and returning to it at some distance in company with different nerve, are found in various parts of the nervous system. The commissural fibres of the optic tracts may be quoted as an example. These fibres leave the centre by one tract, and return to it y the other. It is probably owing to an anastomosis of this kind, etween the posterior and anterior roots of the spinal nerves, that the atter enjoy a slight degree of sensibility. Other instances of a similar ind have been described by Volkmann. In the calf he found an nastomosis between the fourth pair of nerves and the first branch of he fifth pair, forming an arch, from the convexity of which several ranches passed off in the peripheral direction. By far the greater art of these, on microscopic examination, appeared to receive their bres from the fourth; while those fibres of the fifth, which contriuted to the formation of the arch, passed centripetally to the brain, ound up in the sheath of the fourth nerve. There is a similar nervus arch formed between the second or third cervical nerve and the ccessory nerve. Certain fibres, when traced from the former, apear to pass back to the centre in the sheath of the latter. This anasmosis Volkmann found in the human subject, and in several of the ower animals.*

According to Gerber, similar loops are found in the sheaths of pinal nerves. Certain fibres emerge from and return to the nervous entre, forming a loop with the convexity directed towards the periphery, without connecting themselves with any peripheral organ or exture, or going beyond the nerve-sheath. To these loops this anaomist has given the fanciful title, *nervi nervorum*.

Plexuses.—When several neighbouring nerves freely interchange heir fires, a complicated form of anastomosis is produced, which s called a plexus. Four or five nerves, for example, proceed from he spinal cord, for a certain distance without any communication with each other. A division of each then takes place, and from the onjunction of their neighbouring branches new nerves result, which gain subdivide and interchange fibres, and by the free communicaon which is thus established, a network is sometimes formed, (as n the cervical plexus,) in the meshes of which areolar tissue, and ometimes fat, are deposited. Finally, certain nerves emerge from he plexus thus formed, which are composed of fibres derived from everal of the original trunks. Examples of this kind of anastomo-

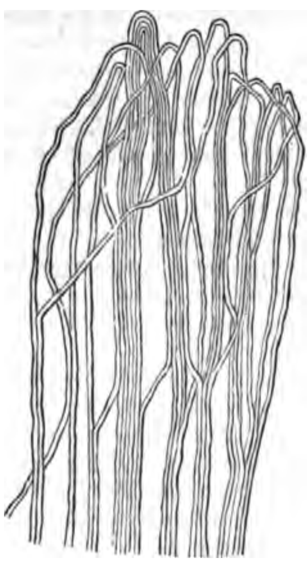
* Müller's Archiv., 1840.

sis are found in connection with the anterior branches of the spinal nerves in the neck, the axilla, the loins, and the sacral region; and there are also plexuses formed in the course of the fifth nerve, the portio dura of the seventh, the glosso-pharyngeal, and the par vagum.

The fibres, which pass through a plexus, notwithstanding the apparent intricacy of their communication, preserve their individuality. This may be proved by irritating a single nerve before it has broken up in the plexus. Such irritation will produce contraction of certain muscles only; of those, namely, to which the fibres of that nerve are distributed. It is probable that, owing to the frequent change of place which the fibres undergo within the plexus, they are brought into communication with a greater number of muscles than if no such subdivision had taken place. Kronenberg's experiments showed that the irritation of certain nerves of the plexus before their subdivision caused the contraction of those muscles only which received filaments from them.*

Termination of Nerves.—The connection which the terminal filaments of nerves form with the proximate constituents of the striped muscle has been already described (p. 161). From that description it will appear that the nervous fibres do not come into immediate communication with the sarcous substance, unless we have recourse to the supposition that some minute elements proceed from those fibres, and penetrate the sarcolemma. Such a supposition has no foundation in anatomy, so far as our present knowledge extends. It is a curious subject of investigation to determine what becomes of the nerve-tubes, which, after the formation of the loops which cross the muscular fibres, take a retrograde course towards the nervous centre. Do they, for instance, return to the spinal cord? and can it be their office to form a second connection with the vesicular matter of the cerebro-spinal centre, the descending fibre coming from the brain, and the returning one being implanted in the gray matter of the cord?

Fig. 60.



Terminal nerves on the sac of the second molar tooth of the lower jaw in the sheep, showing the arrangement in loops.—(After Valentin.)

In the skin the arrangement is plexiform; but this is reducible to loopings, as will be explained in the chapter on Touch.

The arrangement of the primitive fibres in loops has been also seen by Henle on some parts of mucous membrane; in the membrana nic-

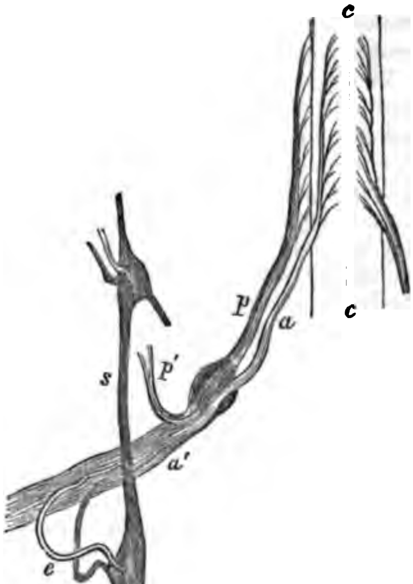
* Plexuum nervorum structura et virtutes. Berol. 1836.

itans of the frog," for example, and in the mucous membrane of the throat in the same animal. A similar disposition has been described and delineated by Valentin in the pulps of the teeth (fig. 60), and we have seen it in the papillæ of the tongue.

The so-called *nerves* of pure sense, the olfactory, optic, and auditory nerves, may more properly be regarded as portions of the brain itself than as mere nerves, for they possess most of the anatomical characters of nervous centres. The intra-cranial portion of the first is as distinctly compounded of vesicular and fibrous matter as a convolution of the brain. In the peripheral expansion of the optic nerve, the retina, it will be hereafter shown that the vesicular elements of a nervous centre are as unequivocally present as in the olfactory bulb. As regards the auditory nerve, there are also some grounds for the statement that the vesicles of gray matter are deposited at its peripheral expansion in the internal ear.*

Of the Ganglionic or Sympathetic Nerves.—The composition of these nerves is essentially similar to that of the cerebro-spinal nerves. They consist of a series of nerve-fibres bound together by areolar tissue which forms their neurilemma. This sheath is, however, denser than in the cerebro-spinal nerves, so that the nerve-fibres are more difficult of separation, and the fasciculated character is not so obvious. It consists almost entirely of white fibrous tissue longitudinally disposed, which are crossed by some fine circular fibres of yellow tissue, surrounding the nerves at various distances from each other. When a nerve is torn up by needles, and treated by acetic acid, numerous small oval cell-nuclei are seen lying in and among the fibres, with their long axes parallel to the latter.

Fig. 61.



Roots of a dorsal spinal nerve, and its union with sympathetic :—*c*, *c*. Anterior fissure of the spinal cord *a*. Anterior root. *p*. Posterior root, with its ganglion. *a'*. Anterior branch. *p'*. Posterior branch *s*. Sympathetic. *e*. Its double junction with the anterior branch of the spinal nerve by a white and a gray filament.

The sympathetic nerves contain the fibres of both kinds, the tubular and the gelatinous, in very variable quantity in different nerves. Thus, the former are numerous in the ramifications of the solar plexus

* See further on these points the chapters on Smell, Vision, and Hearing.

and in the cardiac nerves; and the latter almost exclusively compose one of the fascicles by which the sympathetic communicates with the spinal nerves (fig. 61, *e*): they are so numerous, while the tubular fibres are few, in the sympathetic cord in the neck. In some nerves, the tubular fibres are quite on the surface; and in others, they are enclosed in the axis of the nervous trunk. It is probable that the same change of place between the fibres occurs in these nerves as that which we have noticed in the cerebro-spinal nerves; so that those fibres which at one part of the nerve were superficial, would at another be deep-seated, and *vice versâ*.

The mode of branching of these nerves is essentially the same as that of the cerebro-spinal. But the frequent formation of ganglia in the course of the trunks, and of their ramifications, constitutes a remarkable feature. The branches attach themselves to the exterior of arteries, forming very intricate plexuses, which entwine around them, "hederæ ad modum" (Scarpa). Along these vessels the nerves are conveyed to the tissues; but of the mode in which their filaments connect themselves immediately with those textures we are at present entirely ignorant. The ramifications of the sympathetic seem to be limited to the trunk and head: it has probably no connection, or at most a very limited one, with the extremities.

The connection of the sympathetic system with the brain and spinal cord appears to take place through the cerebro-spinal nerves. Certain filaments connect each spinal nerve to some portion of the ganglionic chain which lies on each side of the spinal column. And a similar connection takes place between ganglia of the cephalic portion of the sympathetic and the encephalic nerves, of which the following may be cited as well-known instances:—The third nerve is connected with the ophthalmic ganglion; the sixth with the superior cervical ganglion; the fifth nerve with the spheno-palatine and otic ganglia. These connecting filaments have been called the roots of the sympathetic; and thus this nerve has been represented as taking an extended origin from numerous points of the cerebro-spinal centre. This is true: but, in dissecting the connection between the sympathetic and the spinal nerves, we find that, for the most part, two distinct fascicles connect them, one of which is white, being composed of tubular fibres; the other is gray, and consists of gelatinous fibres. The former seem evidently cerebro-spinal fibres, which pass to or from the periphery conjoined with the other elements of the sympathetic: but, in the present state of our knowledge, it is difficult to form a correct idea as to the precise object of the latter bundles, or as to the central connection which they form, whether with the ganglion on the posterior root of each spinal nerve, or with the spinal cord. That the sympathetic has intimate and extensive connections with the brain and spinal cord, is abundantly proved, not only by the anatomical statements above detailed, but by the circumstance of which every one is conscious, that pain may be excited in parts supplied from this system of nerves alone, as in the intestines; as well as by the fact that irritation of the spinal cord may produce contraction of muscles which derive their nerves from this source, and

that destructive disease of that organ may occasion paralysis of those muscles.

Of the nervous centres.—The nervous centres exhibit to us the union of the vesicular and the fibrous nervous matter. Indeed, the association of these two forms of nervous substance in a mass of variable shape or size is the main anatomical condition for the formation of a nervous centre. The former is never met with in nerves properly so called, and when a true nerve has a grayish appearance, we find that it is owing to a paucity of the tubular, and an excess of the gelatinous fibres.

All nervous centres are provided with a proper covering which serves to isolate them from adjacent textures, and to protect them, as well as to support their nutrient blood-vessels. In the ganglia this covering is continuous and identical with the neurilemma of the nerves which are connected with them, and it is in every respect of the same structure as the latter membrane.

In the larger centres, the brain and spinal cord, the coverings are of a more complicated kind. They are called *meninges*, membranes. Three of them are enumerated: The *dura mater*, which is external; the *pia mater*, which is in immediate connection with the nervous matter of the centre; and the *arachnoid membrane*, a serous sac intermediate to the two tunics just mentioned, which is evidently destined to facilitate the movements of these organs within their proper cavities. These will be more particularly described farther on.

Fig. 62.

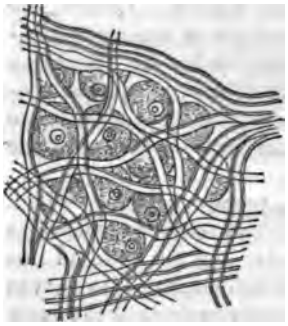
Second abdominal ganglion of the greenfinch, slightly compressed. The course of the nerve-tubes only is represented. *a*. Entering fibres. *b*. Emerging fibres. *i*. Outline of investing tunic, beneath which vesicles exist.—(After Valentin.)

In examining the ganglia, we obtain a good idea of the minute structure of nervous centres in general. A thin slice of one of the larger ganglia, torn up by needles, or a small ganglion from some small animal, serves to show the disposition of the vesicular and fibrous matter in these bodies.

A ganglion may be compared to a plexus, with nerve-vesicles deposited in its meshes (figs. 62, 63). In tracing a nerve into a ganglion, its component fibres appear to separate, and to pass through the ganglion in different directions; some maintaining their original course, others diverging from it for a short way and afterwards returning to it, and others taking altogether a new direction and passing out of the ganglion in combination with other fibres, to form an emerging nerve. A certain degree of interlacement of the fibres thus takes place within the ganglion, and in its interstices are lodged the nerve-vesicles enveloped by their proper sheaths. A great number of nerve-fibres may be traced through the ganglion, so that the emerging nerves may be regarded as resulting from a new combination of the fibres that compose the nerves which entered the ganglion. These, however, are possibly not the only constituent fibres of the emerging nerves, for it has yet to be ascertained whether some

fibres may not take their rise from the vesicular matter of the ganglion, and it is a not less interesting object of inquiry whether some of the entering fibres may not terminate in it. That the nerve-tubes have an intimate connection with the elements of the vesicular matter is apparent from the fact that they lie in close apposition with them, and appear to indent their sheaths of nucleated corpuscles (fig. 57). Sometimes the sheath seems to taper off from the nerve-vesicles, and to become continuous with the nerve-tubes. It is a conjecture by no means devoid of probability, that the processes of the caudate vesicle may, after passing some way, become invested by the tubular membrane and by the white substance of Schwann, and we have seen some appearances to warrant this view (see fig. 56, *c*, *d*). Yet it should be stated, as opposed to this view, that in the gray matter of the cerebellum the caudate vesicles are so placed that their processes pass toward the free surface of the cortical layer, and not into the white matter.

Fig. 63.



A small piece of the otic ganglion of the sheep, slightly compressed; showing the interlacement of the internal fibres, and the vesicular matter.—(After Valentin.)

Besides the tubular fibres, the ganglia contain likewise gelatinous ones, which, however, are more abundant in the sympathetic than in the cerebro-spinal ganglia (fig. 58, *g*). These fibres are, doubtless, continuous with those of the same kind which may exist in the entering or emerging nerves. We may also add, that the vesicular matter does not appear to be confined to the interstices between the fibres, but is likewise found at the surface of the ganglia, lying in immediate contact with their investing tunic.

In the brain and spinal cord, there is a greater separation of the vesicular and fibrous matter than in the ganglia. The former very complicated organ, indeed, consists of various masses which are in all essential points very similar to the ganglia in structure, and doubtless also in function: but its hemispheres are larger masses, of which the interior substance is composed exclusively of fibrous matter, surrounded by a layer of vesicular, which forms a rind or cortex to it. The fibres of the former, however, are prolonged into this cortical layer, and the intermixture of the two forms of nervous substance is thereby effected (fig. 57).

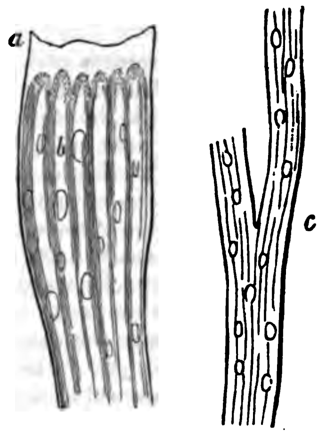
The spinal cord is composed of certain columns of fibrous substance, in which a large number of the fibres take a longitudinal direction. These, in a great degree, enclose a distinct arrangement of vesicular matter, into which, however, as in the cortical layer of the cerebral hemispheres, some, at least, of the fibres of the external white matter are continued, intermingling with its elements. It may, therefore, be stated generally that in the brain the vesicular matter is external and cortical, and in the spinal cord it is internal and al-

npletely surrounded by the white fibrous matter. This dif-
f arrangement is probably to be ascribed to the fact, that
ut the whole course of the spinal cord nerves are being given
it from the encephalon they come only from certain regions.
egions the white matter is superficial; but in the hemispheres,
ch no nerves proceed, it is deep-seated. We shall describe
iutely the disposition of the two kinds of nervous matter in
ro-spinal centre at a future page.

Of the Nerves and Nervous Centres in Invertebrate Animals.

cription above given applies to the human subject, and to the verte-
es generally. In all essential points, so far as the present state of our
enables us to judge, the structural arrangement of the nerves and
ntres of the invertebrate classes accords with this. Some differences,
exist which require to be noticed here. In the lobster, the nerve-
large; the tubular membrane has
transparent, homogeneous ap-
which we have noticed in the
But it encloses many delicate
rarious intervals. Within the tu-
ibrane there is a very thin layer
ite substance of Schwann. The
s are very transparent, and are
er than the average size in verte-
specting the existence or structure
itinous fibres, we can offer no re-
insects and myriapoda, the nerve-
r considerably in size; they are
nto bundles, and are surrounded
sparent sheath of homogeneous
, which accompanies the larger
ns of the nerve-trunks. The white
of Schwann is not so obvious nor
in these nerves as in those of the
l the existence of nuclei (fig. 64)
m resemble closely the gelatinous
the vertebrata. The anatomical
of the vesicular nervous matter of
a do not essentially differ from
e same substance in the vertebrate
far as our observation enables us
The nerve-vesicles with nuclei and nucleoli are equally apparent
ugh in the former they are more transparent, and contain less pigment.

Fig. 64.



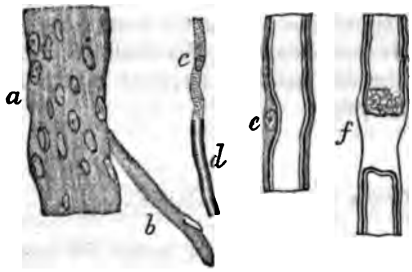
Nervous fibres of insects:—*a*. Transparent sheath. *b*. Nerve-fibres, with oval nuclei. *c*. Shows the bifurcation of the sheath

development of nerve-fibres.—We can add nothing to the
given by Schwann of the development of nerve. The fol-
quoted from Dr. Willis's translation of Wagner's Physio-

nerves appear to be formed after the same manner as the
viz., by the fusion of a number of primary cells arranged
nto a secondary cell. The primary nervous cell, however,
et been seen with perfect precision, by reason of the diffi-
listinguishing nervous cells whilst yet in their primary state,
indifferent cells out of which entire organs are evolved.

When first a nerve can be distinguished as such, it presents itself as a pale cord with a longitudinal fibrillation, and in this cord a multitude of nuclei are apparent (fig. 65, *a*). It is easy to detach individual filaments from a cord of this kind, as the figure just referred to shows, in the interior of which many nuclei are included, similar to those of the primitive muscular fasciculus, but at a greater distance from one another. The filaments are pale, granulated, and (as appears by their farther development) hollow. At this period, as in muscle, a secondary deposit takes place upon the inner aspect of the cell-membrane of the secondary nervous cell. This secondary deposit is a fatty white-coloured substance, and it is through this that the nerve acquires its opacity. This is seen in fig. 65; superiorly, at *c*, the fibril is still pale; inferiorly, at *d*, the deposition of the white substance has occurred, and its effect in rendering the fibril dark is obvious. With the advance of the secondary deposit, the fibrils become so thick, that the double outline of their parietes comes into view, and they acquire a tubular appearance. On the occurrence of this secondary deposit the nuclei of the cells are generally absorbed; yet a few may still be found to remain for some time longer, when they are observed lying outwardly between the deposited substance and the cell-membrane, as in the muscles (*e*). The remaining cavity appears to be filled by a pretty consistent substance, the band of Remak, and discovered by him. In the adult a nerve, consequently, consists, 1st, of an outer pale thin cell-membrane,—the membrane of the original constituent cells, which becomes visible, when the white substance is destroyed, by degrees; 2d, of a white fatty substance deposited on the inner aspect of the cell membrane, and of greater or less thickness; 3d, of a substance, which is frequently firm or consistent, included within the cells, *the band* of Remak."

Fig. 65.



Various stages of the development of nerve:—*a*. Earliest stage. *b*. Detached fibre. *c*. Nucleated fibre in the lower part of which, *d*, the white substance of Schwann has begun to be deposited. *e*. Nucleus in a more fully-formed fibre between the white substance and tubular membrane. *f*. Displays the tubular membrane, the contained matter having given way.—(After Schwann.)

The fully-formed vesicular matter exhibits the persistent state of the cells of primitive development. According to Schwann, the only change which the full-grown cell exhibits consists in an increase of size, and in the development of the pigmentary granules within. According to Valentin's description, the following is the process of development of the nerve-vesicles. In the very young embryos of mammalia, as the sheep or calf, the cerebral mass in the course of formation contains, in the midst of a liquid and transparent blastema, transparent cells of great delicacy with a reddish-yellow nucleus. Around these primitive cells, which we find likewise formed after the

ıe type in the spinal cord, a finely granular mass becomes depo-d, which probably is not at first surrounded by an enveloping cell-mbrane. At this early period of formation the primitive cell still serves its first delicacy to such a degree, that the action of water ses it to burst immediately. In proportion as the granular mass tracts itself within certain limits, a cell-membrane probably is reloped around it, so that the vesicle gradually acquires the exact n and size, and its contents the proper characters, which belong he fully-formed nervous corpuscle.

Of the regeneration of nervous matter.—Our chief knowledge on subject is with respect to the regeneration of the tubular fibres. ny years ago our countryman, Dr. Haighton, in making expe-ents to determine the functions of the vagus nerve, showed that en a nerve is simply divided, without removing any portion of it, on would take place, and the nerve resume its proper office. If considerable piece were excised, so as to leave much interval ween the cut ends, there would be union after the lapse of some e, but not by true nervous fibres, nor in such a way as to restore action of the nerve. It appears, however, from recent observa-ns, of which those of Schwann, Steinruch, and Nasse are the most resting, that true nerve-fibres may be developed in this uniting stance, but apparently in smaller numbers than in the nerve itself. e proof of the regeneration of the true nerve-fibres depends upon the toration of the nerve's function, and the demonstration of the pre-ce of proper nerve-tubes by microscopical examination. Perfect toration of the action of the nerve does not generally take place, ing, most probably, to the fact that the central and peripheral por-ns of the same fibres do not always meet again. The central portion a motor fibre might unite with the peripheral segment of a sensitive ., and thus the action of each would be neutralized.

Nothing satisfactory is known respecting the regeneration of the vous matter of the brain or spinal cord after a loss of substance n injury or disease. When a portion of the brain is removed in mals, its place is supplied by new matter; but, whether this be-nes true cerebral substance, future research with good microscopes st determine.

We refer on the subjects of this chapter to the various works on General Anatomy ted in former chapters, especially to that of Henle; to Müller's, and Wagner's siology; to the articles Nerve, and Nervous Centres, in the Cyclop. Anat. and s.; to the fourth vol. of Sœmmering's Anat. by Valentin (German and French); Valentin, über den Verlauf und die letzten Enden der Nerven; and to Bidder and kmann, Die Selbstandigkeit des sympathetischen Nervensystem. Leipzig, 1842. researches of Bidder and Volkmann on the sympathetic system are of great in-st, if further observation shall confirm them. These authors describe the pecu-fibres of the sympathetic as originating independently of the spinal cord or brain. ir description of these fibres does not exactly accord with what we have seen of gelatinous fibres, nor are we at present prepared to express any decided opinion ecting the accuracy of their observations, which are very favourable to the theory he independence of the sympathetic system.

CHAPTER IX.

VITAL PROPERTIES OF NERVES AND NERVOUS CENTRES.—CLASSIFICATION OF NERVES ACCORDING TO THE VITAL ENDOWMENTS OF THEIR FIBRES. —STIMULI OF NERVOUS ACTION, MENTAL AND PHYSICAL.—VIS NERVOSA—ITS NATURE; IS IT ELECTRICAL?

Of the vital properties of nerves and nervous centres.—There are no textures which exhibit such proneness to molecular change, under the influence of their proper stimuli, as nerve and muscle. It has already been stated in the first chapter (p. 69), that each of these tissues manifests its vital action in a different, although a very analogous way. Muscles, while they are capable of responding to other stimuli, almost invariably act in obedience to that of nerve; and the changes which muscular contraction produces are obvious to our unaided senses in the shortening of the muscle, and in its greater thickness and hardness. Even the alterations in the condition of its sarcous elements may be discerned by the microscope, and have been described at page 170.

The changes, however, which take place in nerve, when in action, are known to us only by the effects which they produce on the sentient mind or on muscular parts. There is no alteration in the physical appearance of the nerve or its fibres, which can be detected by our aided or unaided vision. Yet, from the rapidity with which stimuli applied to nerves produce their effects on distant muscular parts, from the instantaneous cessation of these effects on the removal of the stimulus, and the speedy renewal of them on its reapplication, we can refer the phenomena to nothing so well as to a *molecular change*, rapidly propagated along the course of the nerve from the point of application to the stimulus. And in the instantaneousness of its production, and the velocity of its propagation, we may compare it to that remarkable change in the particles of a piece of soft iron, in virtue of which it acquires the properties of a magnet so long as it is maintained in a certain relation to a galvanic current; these properties being instantaneously communicated when the circuit is completed, and as instantaneously removed when it is broken. A *state of polarity* is induced in the particles of the nerve by the action of the stimulus, which is capable of exciting an analogous change in other particles, whether muscular or nervous; whence results the peculiar effect of the nerve's influence.

Thus, if a nerve be distributed among muscular fibres in the manner described at a former page, it will be capable of exciting muscular contraction, and is properly a *muscular* or *motor nerve;* and it is so connected, at its origin, with the nervous centre, that a change there, whether induced by mental or by physical influence, may be readily communicated to it. When a nerve is distributed upon an expanded surface, as upon the skin or mucous membrane, or is other-

ise favourably disposed for the reception of any physical stimulus om without, it will propagate the change induced by such stimulus the nervous centre; and this change in the centre may produce ı impression upon the mind, giving rise to a sensation; or it may fect a motor nerve connected with the excited one or arising from e nervous centre adjacent to it, and thus may indirectly excite musılar movement. When a nerve is capable of acting in the former ay, it is called a *nerve of sensation*, or *sensitive;* when in the latter, it an *excitor* of a motor nerve.

It is not necessary to suppose any intrinsic difference of structure the nerves which are thus capable of producing effects so manistly different. The action of a nerve depends upon the nature of s central and peripheral connections. It cannot be motor, unless it e intimately connected with muscles; nor sentient, if its relation to e nervous centre be not such as will enable it to affect the sensoum commune. The terms *efferent* and *afferent* are only so far aplicable to certain nerves, as they refer to the direction in which ich nerves *appear* to propagate the change produced in them, or to e position at which the effects of the stimulation become manifest, at direction having reference to the point at which the stimulus is estined to act. In a motor nerve, the ordinary stimulus acts from e nervous centre; but a mechanical or electrical stimulus affecting ich a nerve at any part of its course will cause contraction of the uscles supplied by it below the point of irritation. In the sensitive r excitor nerves, the usual situation from which the stimulus acts at their peripheral distribution; but at whatever point a sentient erve be stimulated, a sensation will be produced, which will be rerred to those parts, and to those only, to which the fibres irritated e distributed; and, wherever the stimulus be applied to an excitor erve, it will, with equal effect, rouse its corresponding motor nerve action. There are no good grounds for supposing that the moleılar change consequent upon the stimulation of a nerve is limited to at part of the nerve which is included between the point stimulated ad the centre, or the muscles, where the effect of the stimulation apears: on the contrary, it is not improbable, that, at whatever point e stimulus be applied, the whole length of the nerve-fibre particiates in the change. This is not unlikely in the case of *motor* nerves. or a continued or violent irritation of a motor nerve in some part of s course, causing spasm or convulsive movement of the muscles it ipplies, may be propagated along its whole length to the centre, and ay there give rise to irritation of neighbouring fibres, whether motor r sensitive, exciting more convulsion and pain. The phenomena of any cases of epilepsy, in which the fit begins with irritation of a few uscles, may be referred to in illustration of this position. And it equally probable as regards *sensitive* nerves. If the ulnar nerve be ritated where it passes behind the internal condyle, a sensation of ngling is excited, which is referred to the sentient surface of the ng and little fingers; and if the irritation be kept up, the skin of ose fingers becomes tender to the touch, its sensibility being very uch exalted. This fact cannot be explained unless upon the sup-

position that the molecular change in the nerve-fibres, produced by the irritation, extends peripherad as well as centrad, exalting the excitability of their distal extremities.

At whatever part of their course sensitive fibres be irritated, the same sensation will be produced, whether the seat of irritation be the centre, the periphery, or the middle of their course, provided only the same fibres are irritated in the same degree. Nothing is more certain than that an affection of the central extremity of the nerve-fibres is sufficient to excite sensations precisely similar to those which the excitation of the peripheral portion of the same fibres would produce. Hence it is that a morbid irritation at the centre is frequently referred to the periphery; and that the sensation of tingling or formication, in the hand or foot, leg or arm, becomes an indication of cerebral or spinal disease. The remarkable fact, that persons who have suffered amputation will continue to feel a consciousness of the presence of the amputated limb long after its removal, derives some explanation from this doctrine. Two cases have lately come before us, in one of which the arm, in the other the leg, was amputated, so long before as forty years; yet each person had the sensation of his fingers or toes as distinctly as immediately after the operation. And not only is there, in such cases, the consciousness above referred to, but likewise, when the principal nerve of the limb is irritated, the patient complains of pains or tingling, which he refers to the amputated fingers or toes.

It may be stated, in confirmation of the view above taken, that in many cases of complete paralysis of a limb from *cerebral* disease, the patient is not conscious of its presence, and really feels as if it did not exist. We have known instances in which this unconsciousness has been so great, that when the paralyzed part came in contact with some sensitive portion of his body, the patient for a time believed it to belong to another person, or imagined it some entirely foreign substance. In such cases the affection of brain necessary to create the feeling cannot be produced in consequence of the morbid state of that organ.

The distinction which has been made between nerves of *common* and of *special* sensation, is indicated by the fact, that while a stimulus to the former causes pain, that to the latter gives rise to a peculiar or special sensation, as of light, sound, or taste. These nerves are so organized at their periphery as to be peculiarly adapted to receive impressions from the agents to which they specially respond: and in this, as well as in their connection with some special part of the great centre of sensibility, consist their main anatomical peculiarities (see p. 69).

The same law of nervous action applies to these nerves as to those of common sensation. Thus, their ordinary mode of action is to propagate to the centre impressions made at the periphery; but irritation at any part of them may give rise to their peculiar sensation; and if the brain be stimulated at the part whence these nerves arise, similar sensations are produced. Such phenomena of vision and hearing, to which the term *subjective* has been applied, are familiarly known to

ractitioners, as not unfrequent forerunners of more serious symptoms f cerebral disease. Muscæ volitantes, ocular spectra, tinnitus aurium, e instances of these phenomena, which, although of every-day ocurrence, ought always to excite the attention of the medical man, as dicating some departure from the normal state of the optic or audiry nervous apparatus. Pressure on the eyeball, a galvanic current assed through it,* rotation of the body, are capable of giving rise to milar phenomena, by exciting the retina, or the central connecons of the optic nerve. A sense of giddiness, similar to that proaced by the means last named, is also a very common symptom of rebral affection arising from a disturbed circulation, or from the lood being defective in one or more of its staminal principles, or itiated by some morbid element.

The nervous trunks as they exist in different regions are usually ompound; that is, they contain fibres of different endowments. In me situations, it is true, the fibres of one kind predominate so much to give the trunk the physiological character which belongs to em; but it likewise enjoys in a proportionate degree the functions those fibres, which are few in number. For example, the facial rve, or *portio dura* of the seventh pair, is called motor because it almost wholly composed of motor fibres; but it contains, besides, very much smaller number, some sensitive filaments, which it obably derives from anastomoses with neighbouring nerves. The ird, fourth, and sixth pairs of nerves may be quoted as of similar nstitution to the facial. In the ramifications of the fifth nerve, on e other hand, the filaments of sensation are predominant; those of otion being much fewer, and confined to the branches of its inferior axillary division.

It is at the points of emergence of the roots of the nerves from e nervous centres that we find the most complete isolation of funcn. This is well exemplified in the spinal nerves and in the fifth ir. These nerves emerge from their respective centres by two ndles of fibres, of which one is sensitive, the other motor; the forer having almost always the distinctive features of greater size than e latter, and of having a ganglion formed upon it. But, even in ese instances, it has lately been made a matter of question whether e smaller root, which experiment has satisfactorily shown to be otor in its function, does not also contain a very slight proportion sensitive filaments.

The stimuli by which the action of nerves is ordinarily provoked e of two kinds, *mental* and *physical*. In all voluntary actions, an act the mind is the excitant of the nerve. Sensations are caused by e influence of physical agents upon nerves, which communicate with e *sensorium commune*. The change in the nerve, by reason of this mmunication, gives rise to a corresponding affection of the mind. is wonderful how quickly such changes are propagated, and with at precision they are perceived by the mind, although the physical

* A strong sensation of a flash of light may be produced by passing a galvanic rrent in the close vicinity of the eyeball.

excitant may itself be a fine point invisible to the naked eye, applied with the slightest force, and coming in contact with a spot equally difficult of appreciation. If the communication between the nerve and the centre be cut off, the will can exert no influence upon the muscles supplied by the nerve below the section; nor will the mind perceive any stimulus applied to parts which derive their nerves from it below the separation. And the reason is obvious; the solution of continuity of the nerve interrupts the propagation of the change which the mental or physical stimulus excites in it. In the case of the voluntary nerve, the mental stimulus is propagated no further *peripherad* than the point of section: and in that of the sensitive nerve, the change travels no further *centrad* than the same point. That the interruption is caused solely by the solution of continuity, and not by any alteration in the properties of the nerve, is proved by the fact that the lower segment of the motor nerve will still continue to respond to a physical stimulus. Mechanical or chemical irritation, or the passage of an electric current across it, will cause its muscles to contract. Such a degree of injury to a nerve as will destroy the continuity of the nervous matter within the tubular fibres is likewise sufficient to destroy its power as a propagator of nervous change. This effect will be produced by tying a ligature very tightly round a nerve, or by pressing it very forcibly between the blades of a forceps. The paralysis which results from the compression of a nerve by a tumor, or in any other way, is no doubt due to a similar solution of continuity in the nervous matter.

From these facts we draw the important inference that, in propagating the influence of a stimulus, either from periphery to centre, or *vice versâ*, nerves are not mere passive conductors. The whole extent of the fibre between the point stimulated and its peripheral or central connection is the seat of change. How necessary, then, to the normal action of nerves must it be to preserve their physical condition in a healthy state! A morbid fluid impregnating a nerve at any point may irritate it, or may suspend or destroy its inherent property by modifying its nutrition. It is thus, likewise, that nerves may be paralyzed by soaking them in a solution of opium, or of belladonna, aconite, tobacco, or other powerfully sedative or narcotic substances, or that they may be unduly excited by applying a solution of strychnia. The contact of a solid body with a nerve may irritate and keep up a continual state of excitement, if it do not destroy its properties. A spicula of bone in contact with nervous fibres is often the cause of the severest forms of neuralgia. That alteration of nutrition which we call inflammation may produce like effects. Various physical agents are followed by similar consequences. The benumbing influence of cold is explained in this way. Exposure to a continuous draught of cold air is a frequent cause of facial paralysis. How instantaneously will the giving way of a carious tooth occasion toothache by exposing the nerves of its pulp to the irritating action of the air, or of the fluids of the mouth! And heat is equally injurious to the physical constitution, and consequently to the action, of nerves.

The organic change, whatever be its intrinsic nature, which stimuli, hether mental or physical, produce in a nerve, develops that won-erful power long known to physiologists by the name *vis nervosa*, e nervous force. This force is more or less engaged in the play of l the vital functions, whether organic or animal. In the former its fice is to regulate, control, and harmonize, as will be hereafter ex-ained; in the latter, it is the main-spring of action, without which one of the phenomena can take place. It is the natural excitant of uscular motion, and the display of that wondrous power depends pon its energy. Unless there were vigour in the development and plication of the nervous force, a well-formed muscular system would of little avail, for it would quickly suffer in its nutrition if deprived that exercise which is so necessary to it.

Although the workings of the mind are doubtless independent of e body, experience convinces us that in those combinations of ought which take place in the exercise of the intellect, the nervous rce is called into play in many a devious track throughout the in-icate structure of the brain. How else can we explain the bodily haustion which mental labour induces? The brain often gives way, ke an overwrought machine, under the long-sustained exercise of a gorous intellectual effort; and many a master-mind of the present a former age has, from this cause, ended his days "a driveller and show." A frequent indication of commencing disease in the brain the difficulty which the individual feels in "collecting his thoughts," e loss of the power of combining his ideas, or impairment of me-ory. How many might have been saved from an early grave or e madhouse, had they taken in good time the warning of impend-g danger which such symptoms afford! The delicate mechanism the brain cannot bear up long against the incessant wear and tear which men of great intellectual powers expose it, without frequent d prolonged periods of repose. The precocious exercise of the tellect in childhood is frequently prejudicial to its acquiring vigour manhood, for the too early employment of the brain impairs its ganization and favours the development of disease. Emotion, hen suddenly or strongly excited or unduly prolonged, is most de-ructive to the proper texture of the brain, and to the operations of e mind. Our lunatic hospitals afford many examples of men, the orking of whose minds has been wholly or partially destroyed by e shock which a sudden reverse of fortune, or the loss of some near d dear relative, may have occasioned. Constant or frequent ex-sses in the use of ardent spirits may probably be thus injurious in o ways; first, by the direct influence of the alcohol on the cerebral re itself, producing a chemical alteration in the nervous substance; d secondly, by the frequent mental excitement which the use of such stimulus induces.

Can we form any conception of the nature of this wonderful power, hich is so intimately connected with the functions of our bodies d with the working of our minds? That it presents many points resemblance to electricity, a comparison of the laws of these two rces leaves no room to doubt; although there are abundant reasons

for questioning their identity. The comparison may be best instituted between the nervous power and the force of voltaic electricity, or current affinity, as it has lately been called, which is developed in the galvanic battery. For the production of this force the ordinary requisites are two dissimilar metals, and an interposed compound liquid. When the metals are brought into contact with each other, a chemical action immediately commences, and an electric current sets in a definite direction, namely, from the metal which exerts the greatest affinity for one of the elements of the interposed liquid towards the other metal. Thus if zinc, platinum, and dilute sulphuric acid be used, the fluid is decomposed ; its oxygen is attracted to the zinc, which being oxidized and uniting with sulphuric acid, sulphate of zinc is rapidly formed, and dissolved as quickly as formed, in the liquid; its hydrogen is evolved at the platinum. So long as there is fluid for decomposition, and so long as contact between the metals is maintained, these phenomena will continue. During the continuance of these chemical actions, the metals as well as the interposed fluid are supposed to be in a peculiar molecular condition, upon which the development of force in a current form depends. Commencing from the immersed portion of the zinc, each particle, whether of metal or fluid, communicates its peculiar state to that which succeeds it, until the whole circuit, from the zinc through the fluid to the platinum, and back again to the zinc, is in the same state, one, namely, of *polarity* or *electrical tension.* A similar state may be induced in glass, sealing-wax, &c., by friction; or in two dissimilar metals in intimate contact, by heating them at the place of junction; or in one metal, as a coil of platinum wire, by heating it unequally (thermo-electricity). The simple contact, indeed, of two plates of different metals with perfectly clean surfaces is sufficient to excite a state of polarity in each.

In the development of the galvanic current in the battery, one plate or metal may be regarded in the light of the generator of force, the other as its propagator or conductor. The former has therefore been called the *positive*, the latter the *negative* pole. The absolute contact of the metallic plates themselves is not necessary. It will suffice if they be connected by any material which is itself capable of serving as a conductor. A piece of platinum wire, for instance, extended between the two plates, although it actually connects only a very small portion of the surface of each, will answer the purpose. From such an arrangement it may be concluded that, during the development of the galvanic current, the conducting metal is in a state similar to that of the generating plate, for the temperature of the conducting wire is raised considerably; and, when there is much energy of action, the wire is melted.

The existence of a galvanic current is readily detected, even when of feeble intensity, by certain phenomena, which are now familiar to those who conduct such investigations. If the poles of a battery be connected by conducting wires with a delicate galvanometer (electro-dynamic multiplier), the needle is obviously deflected during the passage of the current, and returns to its previous position when-

ver the current is interrupted. By making and breaking the connection, in rapid succession, the needle moves to and fro with corresponding rapidity and energy. So delicate is this test of galvanic action, that it will detect even the very feeble current which results from the heating of two dissimilar metals, or from the partial heating of a coil of platinum wire. As this is the most delicate test, so is it also the most constant, and it has the additional advantage of enabling the observer to judge of the direction of the current from the position which the needle assumes under the electric influence.

When a galvanic current is made to pass through certain liquids, as dilute sulphuric acid, solution of iodide of potassium, of sulphate of copper, &c., it induces such an amount of disturbance of the attractions existing in them as to cause their decomposition, and give rise to chemical actions of a similar kind to those which take place in the generation of the current (electrolysis). This, therefore, becomes a test of the presence of galvanic action. The decomposition of iodide of potassium will detect the existence of a current developed by a single pair of plates, and iodine will be set free at the positive pole.

Further tests of the presence of galvanic action are found in the magnetization of a steel needle placed within a coil of wire through which the current is made to pass; and in the evolution of heat and light, which takes place when the circuit is completed or broken. This latter effect, however, does not occur from currents of very feeble intensity.

Let us inquire how far the phenomena of the nervous force correspond with those of this current electricity, and whether it will respond to any of the tests just described.

It has already been remarked that the instantaneousness with which nervous power is developed, when a mental or physical stimulus is applied to a nerve, resembles remarkably the rapid evolution of the galvanic force throughout the whole circuit, the instant the necessary contacts are completed. And both cease with equal rapidity when the conditions for their production are destroyed.

Some analogy is apparent in the conditions which are requisite for the development of both forces. The dissimilar metals and the interposed fluid, which we have seen to be necessary for the production of the galvanic force, may have as analogues for the development of the polarity of nerves, the two kinds of nervous matter (the vesicular and fibrous), and the blood. Nervous power is never developed from a centre without the conjoint action of these two kinds of nervous matter. The analogy fails, however, when we compare the relation of the metals in the battery with that of the gray and white matter in the nervous centre. The former need not have any connection but such as a conducting wire of ever so minute dimensions passing from one to the other is capable of effecting; that is to say, union of a few points of one metal with as many of the other, is sufficient for the generation and transmission of the polar state. In the nervous centres, however, the points of contact are probably most numerous. The vesicles of the gray matter certainly are

brought most extensively into connection with the nerve-fibres; and there is much to justify and confirm the opinion that each fibre is connected with a vesicle, and that each vesicle, at least of the caudate kind, may be regarded as the point of departure of one or more fibres. If such an arrangement exist, we may regard each nerve-vesicles, and the fibres emerging from it, with the blood-vessels which play around it, as a distinct apparatus for the development of nervous polarity.

There appears to be a provision for the insulation of the central axis of each nerve-fibre in the white substance of Schwann; but there is no such arrangement for insulating the vesicles. In like manner, we can insulate the galvanic current by covering the conducting wire with silk, or some other non-conductor, and thus cause it to pass through an indefinite length of wire disposed in coils, or through any number of separate wires disposed parallel to each other, which may be brought into connection with the metals.

These remarks are clearly most applicable to those nervous actions which emanate *from* a centre. But in those in which the nervous force is propagated *to* a centre, as when pain is excited by touching a nerve, or in the excitation of the motor nerve of an amputated limb by artificial stimuli, the analogy of the mode of its development with that of the galvanic force is not so obvious. Still, when we remember how easily thermo-electric currents may be excited by the disturbance of the equilibrium of heat in a wire of even a single metal, it seems not unreasonable to refer this excitability of nerve to some similar proneness to change in it.

Nothing is more certain than that a very slight mechanical or chemical stimulus to a nerve, whatever be its proper vital endowment, is capable of producing in it that state of polarity on which we suppose the manifestation of nervous force to depend; and it seems not incorrect to imagine that, in the battery, the point of departure of the galvanic action may either be at the poles or at the battery itself, according to the place at which the completion of the circuit takes place; thus affording a more marked analogy to the two kinds of nervous actions above referred to. Thus the conducting wires may be in contact with each other, and with their respective metals; but, if there be no fluid interposed, there is no action. The instant the fluid is added, the current begins; and in this case its point of departure may be regarded to be from the battery—in analogy with those nervous actions which proceed from the centre. On the other hand, the arrangements of the battery itself may be perfect, but action will not begin until the circuit is completed by bringing the conducting wires into contact. In this case, the polar change may be said to commence at this point of contact, and to travel to the battery, in a manner analogous to that in which nervous action is propagated from the periphery to the centre. In both cases, moreover, so long as galvanic action continues, the *whole* apparatus is in the polar state: and so long as nervous action continues, the particular nervous apparatus involved (vesicular matter and nerve-fibre) must be considered to be in a state of polarity through its *whole* extent.

Thus far we remark unquestionable analogy in the mode of development and of propagation of the electrical and nervous forces. We must not, however, omit to notice the following points in which the analogy does not hold good. In the development of nervous power, there is nothing, so far as our present anatomical knowledge enables us to decide, resembling that completion of the circuit which is the necessary prelude to galvanic action, or the interruption of it which is followed by the cessation of that action. The mental or physical stimulus, which must be regarded as a necessary element in every nervous action, stands in lieu of the former; but how it could accomplish the completion of a nervous circuit is a question at present involved in the greatest obscurity. It is, indeed, a favorite notion with some, that the looped arrangement of the peripheral nerve-fibres, in muscles and on some sentient surfaces, forms part of a nervous arc, which is completed at the centre; nor is it impossible to conceive a mechanism by which the completion or interruption necessary for the development or the stoppage of the nervous power might be accomplished. But it would be hazardous to speculate on such a subject until anatomical research has revealed to us more information respecting the exact disposition of the elements of the vesicular matter.

The gelatinous fibres appear to want the provision which we have noticed in those of the tubular kind for insulating the nervous power. They supply the unstriped muscular fibres, which probably require a stimulus less definite, as well as of less intensity, than that necessary to excite and regulate the action of the striped fibres. This difference of character in the conducting fibres is worthy of note in making comparison between the respective modes of action of the nervous and electric forces.

We come now to inquire whether, by means of the ordinary tests for electricity mentioned in a former page, we can obtain any evidence of the identity of the nervous and electrical forces. The results of experiment certainly afford no support to the advocates of the electrical theory; and indeed it will be seen that there are difficulties in the way of obtaining the necessary conditions for a satisfactory result, which of themselves invalidate the experiments which have been reported to prove favourable to that theory.

Attempts have been made to affect the galvanometer by bringing the nerves of living animals into connection with it. This is done by inserting wires into the exposed nerve, and attaching their opposite extremities to the galvanometer. When the nervous power is excited so as to cause muscular contraction, the needle, it is said, is deflected.* The experiment, however, has failed in the hands of Prevost and Dumas, who are advocates of the electrical theory, as well as in those of Person, of Müller, and of Matteucci; and on several trials we have been unable to observe the slightest movement of the needle. Person connected the wires of a galvanometer with the surfaces of the spinal cord in kittens and rabbits, in which spas-

* David, quoted by Müller, p. 685.

modic action of the muscles had been excited by the influence of nux vomica, and could not discover any evidence of electrical action. It has been also affirmed that needles introduced into the nerves of a living animal become magnetic, so as to attract iron filings. No such result, however, could be obtained by Müller, or by Matteucci, from their repetition of these experiments. The latter philosopher took the precaution of employing astatic needles for the purpose, but could discover no trace of magnetization. He also introduced the prepared limbs of a frog into the interior of a spiral covered on its inside with varnish: the extremities of this spiral were united to those of another smaller spiral, into which he introduced a wire of soft iron. The nerves of the frog were irritated to excite muscular action, and at the same time Matteucci sought to ascertain if an induced current would traverse the spirals, and magnetize the wire. But, he adds, all his endeavours were useless.

No one has tried to obtain a spark from a nerve during its action, as a test of the electrical nature of the nervous power. Nor have any experiments been devised with a view to ascertain whether decompositions similar to those which occur in electrolysis may be effected by it. The separation of certain elements from the blood, in the various secretions, has, indeed, been attributed to a kind of electrolytic influence of the nerves upon the secerning organs. But it has been proved that the secretions may go on to a considerable extent independently of nervous influence, and it seems highly probable that the nervous system can affect the act of secretion only through its influence upon the blood-vessels of the secreting organ.

But even were it certain that an electrical current passes along the nerve-fibres during nervous action, it does not seem likely that the required evidence of such a current could be obtained from any of the experiments above detailed. For if the nerve-tubes are to be regarded as insulated conductors, of which the central axis is the active portion, and the white substance of Schwann merely the insulator, sinking a needle between these fibres will not obtain that contact with the true conducting material which is necessary to affect the galvanometer. Let it be remembered that these nerve-fibres are of microscopic size; and that, when a needle is sunk into a bundle of them, it does not pierce the nerve-tubes, but passes in between them, and is separated from their central axes by the insulating structure. And were the electric current, passing through such minute conductors as nerve-fibres, of sufficient intensity to magnetize a needle, it is scarcely possible to conceive that it would be completely or perfectly insulated by the delicate membranes which invest the central axis. Yet, without some provision for very complete insulation of the several conductors in such a bundle as a nervous trunk, it is obvious that disturbances must continually arise from the secondary currents induced in neighboring fibres by the electricity passing through those in action.

The proofs, therefore, of the passage of an electric current through the nerve-fibres during nervous action must be held to be altogether defective. Not only is experimental evidence wanting to support the

electrical theory, but certain facts are admitted which greatly invalidate it. Of these, a very important one has been adduced in the preceding paragraph. The following may be added, some of which have already been adduced by Müller.

1. The firm application of a ligature to a nerve stops the propagation of the *nervous power* below the points of application, but not of *electricity*. The nervous trunk is as good a conductor of electricity after the application of the ligature as before it.

2. If a small piece of a nervous trunk be cut out, and be replaced by an electric conductor, electricity will still pass along the nerve, but no nervous force, excited by stimulus above the section, will be propagated through the conductor to the parts below.

3. Nervous fibre is not a better conductor of electricity than other tissues. Matteucci assigns to muscle a conducting power four times greater than that of nerve or cerebral matter; and Weber states that no substance in the human body is so good a conductor as the metals. From our own observations on this subject, made with the *most delicate* instruments, we are led to state that both nerve and muscle are *infinitely worse* conductors than copper, and that we have failed in detecting any appreciable difference in the conducting power of these two animal substances. In fact, their power of conduction does not rank above that of water holding in solution a small quantity of saline matter.

From the preceding review of the arguments for and against the theory of the identity of the nervous force and electricity, we are led rather to reject than to adopt it. The same reasons induce us to regard the nervous force as a power developed in the nervous structure under the influence of appropriate stimuli; as muscular force is developed in muscle under similar influence. Both tissues are characterized by their tendency to assume a polar state, different in each, although analogous, in obedience to certain excitants. That this polarity bears a remarkable analogy to that which may be produced in inorganic matter is evident. Further observation and research conducted with a full knowledge of the details of anatomy, as well as of the laws of the polar forces, as displayed in inorganic substances, will doubtless throw great light on this intricate subject; for, as Faraday remarks, if there be reasons for supposing that magnetism is a higher relation of force than electricity, so it may well be imagined that the nervous power may be of a still more exalted character, and yet within the reach of experiment. (*Phil. Trans.*, 1839.)

Of the electrical fishes.—The fact that some fishes possess a peculiar electrical apparatus, which they are enabled to discharge under voluntary influence, is supposed by the adherents of the electrical theory to favour their views. The *torpedo*, the *gymnotus electricus*, or electrical eel, and the *silurus electricus*, are the best known of the electrical fishes. From the two former, the most unequivocal evidence has been obtained by Walshe, Davy, Linari, Matteucci, and recently by Faraday, that electricity is discharged. Conductors or

non-conductors are affected by the electrical apparatus of these fishes just as by ordinary electricity: a chain of several persons, of whom those at the extremities touch the fish, feel the shock as they would that of a Leyden jar. The sensation produced by the shock from the fish is exactly that which is caused by accumulated electricity as developed by the ordinary machine. A spark has been obtained during the discharge: chemical decomposition or electrolysis has been effected by it. The galvanometer is also readily disturbed, and indicates that the current passes from the anterior to the posterior part of the animal. And a needle has been made a magnet when placed in a helix through which the current passes. These effects have been obtained from the torpedo and the gymnotus.

It is further shown that the electricity cannot be developed in these animals if the organ be removed, or if its communication with the brain be cut off. If the nerves of the organ of one side be cut, it will cease to develop electricity; but the opposite organ will continue to act perfectly. When the organ is partially cut away, the remaining portion continues to discharge; or, if some of its nerves be cut, that portion of which the nerves are entire will continue to develop electricity. The nerves excite some change in the organ which causes the development or discharge of electricity, but no traces of an electrical current can be detected in the nerves themselves. If the nerves of an electrical organ be cut, irritation of those segments of them which adhere to the organ will excite discharges, just as the irritation of muscular nerves under similar circumstances will cause contractions; or direct irritation of portions of the organ itself will produce discharges (Matteucci). Any general excitation of the nervous system will cause discharges; thus strychnine, while it throws the muscular system into spasms, provokes frequent and violent discharges of the electrical organs.

From these observations it seems impossible to adopt any other conclusion than that the electrical organ is the *generator* of the electricity; or, at least, that it may collect and accumulate the electricity generated all over the body in the ordinary nutritive processes. This latter opinion, however, is rendered unlikely from the imperfect conducting power of animal substances, unless further research should develop some channels by which electricity generated at a distance might be conveyed to the electrical organ. Whatever view of the case be adopted, it is difficult to discover in the facts above stated respecting the electrical fishes any support to the electrical theory of nervous power. On the contrary, the very existence of a peculiar organ for the specific purpose of generating electricity would appear adverse to such a doctrine. Were the nervous centres the source of electricity, surely an arrangement, of a less complex character, and deviating to a less extent from the natural structure of other fishes of the same genus, would have sufficed for the manifestation of the peculiar power of the electrical fishes.

Some insects (the glow-worm for instance), and other creatures, possess the faculty of generating light. The power resides in a particular organ, and is regulated by the nervous system. It is strik-

ingly analogous to that by which electricity is developed. Yet no one would assign the nervous system as the source of the luminous emission. Nor are we justified in affirming from the one instance that the nervous power is electricity, any more than we should, from the other, be authorized in asserting that the nervous power is light.

On the subjects discussed in this chapter, reference is made to Müller's Physiology by Baly; Daniell's Chemistry; the articles "Animal Electricity" and "Animal Luminousness," in the Cyclop. Anat. et Physiol.; Matteucci, Traité des Phénomènes Electrophysiologiques des Animaux.

CHAPTER X.

ARRANGEMENT OF THE NERVOUS SYSTEM IN VERTEBRATA.—IN INVERTEBRATA.—NERVOUS CENTRES IN MAN.—THEIR COVERINGS OR MENINGES.—THEIR VENOUS SINUSES.—THE SPINAL CORD.—THE ENCEPHALON.—THE CIRCULATION WITHIN THE CRANIUM.

THE leading subdivision of the animal kingdom into Vertebrate and Invertebrate animals is so obviously sanctioned by the disposition of the nervous system peculiar to each, that no naturalist hesitates to adopt it. In the *vertebrate* animals, an osseous or cartilaginous column, composed of separate pieces united by amphiarthrosis, forms the principal support and bond of connection for the other parts of the trunk. This column encloses a canal, within which is placed that portion of the nervous centres called the spinal cord, or marrow, with some of its nerves. At its anterior or upper extremity, the component pieces of the column are so modified as to form a dilated cavity, the cranium, in which another portion of the central nervous system, the brain, or encephalon, with part of the nerves connected with it, is contained. In the *invertebrate* animals generally there is no internal skeleton, if we except the slight traces which exist in the cephalopodous mollusks; but in many of them a modification of the external integument affords the requisite amount of protection and support to the soft tissues and organs. The nervous system, the central part of which is disposed either in detached masses, or in a series along the abdominal surface of the animal, receives no special protection from this external skeleton.

The brain and spinal cord, in the vertebrate classes, form a central axis with which all other parts of the nervous system are connected. The former is evidently an aggregate of gangliform swellings, each possessing the characters of a nervous centre, but so connected with the others, that their functions are in no small degree mutually dependent. The latter has throughout its entire length all the characters of one uniform nervous centre, of cylindrical shape; but experiment has shown that, if divided into segments, in animals

tenacious of vitality, each portion may exert an independent influence on that segment of the body whose nerves are connected with it. From this fact we may properly regard the cord also in the light of a ganglion compounded of smaller ones, which have been, as it were, fused together. And certain anatomical indications in the lower animals, as well as in man, favour this view; thus, in the common gurnard (*trigla lyra*), there is a series of gangliform swellings situate on the posterior surface of the cervical portion of the cord at its upper part, from which large nerves pass off to the feelers; and in all animals the cord exhibits a distinct enlargement, at each segment with which large nerves are connected, or a contraction, if the nerves be of small size and of comparatively little physiological importance.

The cerebro-spinal axis, with the nerves pertaining to it, constitutes the greatest portion of the nervous system of the human subject and of the vertebrate animals. The sympathetic system, however, is connected with a large number of those parts on which the principal organic functions depend. This portion of the nervous system always bears a direct relation in point of development to that of the cerebro-spinal portion, with every part of which it is very intimately associated. If we except the olfactory, optic, and auditory nerves, there is no nerve with the origin of which it does not form a connection. Its segments remain separate, as distinct ganglia, connected, however, by intercommunicating cords passing from one to the other, by which the continuity of the chain on either side of the vertebral column is maintained. In mammals and birds the sympathetic is fully developed; but in some reptiles and fishes it is partly deficient, and its anterior part which is wanting, is supplied by the vagus nerve. In the cyclostomatous fishes, as the lamprey, it is wanting altogether, and the vagus seems to supply its place. In no animal is it so fully developed as in man.

Arrangement of the Nervous System in Invertebrata.

It is foreign to the purpose of this work to enter into details of comparative anatomy. The following paragraphs are merely intended to call the reader's attention to the general plan of the nervous system in the Invertebrata. The arrangement adopted is that suggested by Professor Owen.

The Invertebrate animals may be classed in three groups, according to the prevailing type of arrangement of the nervous system. 1. The first, or *Nematoneuroæ*. exhibits no other trace of nervous system than is to be found in simple threads or filaments. In the *asterias*, one thread surrounds the mouth, and others pass from it to the rays; and in the *strongylus gigas*, a slender nervous ring surrounds the upper part of the gullet, and from it a single thread is continued along the ventral surface to the opposite extremity, where another nervous loop is found surrounding the anus. No distinct evidence of the existence of ganglia in animals included in this group has been obtained. It would be premature, however, to suppose that the absence of gangliform swellings implies that of vesicular nervous matter.

2. The second group of animals is designated *Heterogangliate*, from the unsymmetrical disposition of the nervous system. The principal portion of it consists in a ring surrounding the gullet, on which one or more ganglia are placed. In the *ascidia mamillata* there is but a solitary ganglion, which regulates the orifices

of ingestion and egestion by nerves which it sends to their respective sphincter muscles. And in all the other classes of mollusks the nervous system is the more complex, as the kind and number of the vital actions demand a higher degree of organization. In conchifera, for instance, ingestion of the food, respiration, and locomotion have distinct organs assigned to them, and accordingly the nervous system is so disposed that there is a nervous centre or ganglion in immediate relation to the principal organs connected with each of these functions. Thus, in the more perfect animals of this class we find, 1, two *œsophageal* ganglia situate near the mouth, connected to each other by nervous filaments, which form a ring round the gullet. These ganglia are connected with all the rest, and probably exercise an influence upon them, as the principal centre of the nervous system or the brain. 2. There is a *branchial* ganglion, which presides over the function of respiration. When there is but one respiratory organ, this ganglion is single; but it is double when there are two branchiæ. From this source are supplied not only the organs of respiration themselves, but also the muscles upon which the respiratory movements depend. The posterior adductor muscle, the mantle, and intestine, derive nerves from it. 3. We find a *pedal* ganglion, which is immediately connected with the locomotive function. This ganglion exists only in those genera in which a muscular organ called the foot is developed, and its size is always in direct proportion to the muscular power of that organ: it is situated at its base, and imbedded in it. We find it, therefore, in the mussel (*mytilus*), but not in the oyster. The development of organs of sense in the higher animals of this group demands an increased development of the cerebral ganglion, as is the case in the gasteropod and cephalopod mollusks. And the great powers of locomotion enjoyed by the latter animals require a high development of the pedal ganglion, and a multiplication of smaller ganglia in connection with the muscular apparatus of their arms or tentacles. These organs are supplied with nerves from the subœsophageal ganglion; and, where suckers exist upon the arms, an additional series of ganglia is provided, which seem to exert an especial influence in the exercise and the maintenance of their suction power.

3. The third, or *Homogangliate* group, is distinguished by the symmetrical arrangement of the nervous system. The articulate classes furnish examples of this type. A bilobed ganglion is situated above the œsophagus, and is connected with the organs of sense when they are present. From this there proceeds on each side of the œsophagus a nervous cord to a pair of ganglia beneath that canal, and therefore on the ventral surface. To these succeed, in most of the articulata, and likewise on the ventral surface, a pair of ganglia for each segment, from which are supplied the nerves to that segment. The ganglia are connected throughout, however, by cords of communication from the cephalic to the caudal segment. The number of pairs of ganglia is always in accordance with the number of segments of the animal; and, if some of these segments be fused together, a similar coalescence of the ganglia takes place. This is observed in insects in the change from the larva to the perfect state; and, in some genera of crustacea, the permanent form of the nervous system has obvious relation to peculiarity in the shape of the body. The annular arrangement of the ganglia in the body of the common crab (*cancer*), and of the king-crab (*limulus*), is evidently explained by reference to the compressed form of the body, and the articulation of the legs around it.

Some additional ganglia are met with in a few animals of the homogangliate group, which seem to represent rudimentary conditions of the sympathetic system. These have been best observed in insects, and they are described under the name of stomatogastric ganglia. They are two or more in number, connected by delicate filaments with the cephalic ganglia; and they give off long nerves, which supply the digestive organs and the dorsal vessel, or heart, and which, in some instances, unite with small ganglia in the abdomen to be distributed on the viscera of that cavity.

Of the Spinal cord and Brain.—The cerebro-spinal centre is enclosed in certain membranes or *meninges*, which are three in number; the *dura mater*, the *arachnoid*, and the *pia mater*.

The *dura mater* consists of white fibrous tissue. It is thick, very

strong and flexible, without being elastic. Its fibres are disposed on different planes, but freely intermingle. At certain situations it separates into two layers to form the venous canals, which are called *sinuses*. The inner surface of the cranial cavity is covered by dura mater, which adheres closely to the bones, and serves as an internal periosteum to them; and certain processes of the dura mater pass into the interior of the cranial cavity, dividing it into compartments, which contain certain segments of the encephalon. These processes are, 1. The *falx cerebri*, which extends from the crista galli to the occiput along the line of the sagittal suture, and forms a vertical septum between the hemispheres of the brain. 2. The *tentorium cerebelli*, which is attached to the occipital bone along the groove for the lateral sinus, and to the posterior superior edge of the petrous bone. This process forms a vaulted roof to the compartment which contains the cerebellum, and extends between the upper surface of that organ and the inferior surface of the posterior cerebral lobes. In some animals, the cat, for instance, it is partially replaced by bone. 3. The *falx cerebelli*, a small nearly vertical process which descends from the internal occipital protuberance, and occupies the notch between the hemispheres of the cerebellum.

In the spinal canal, the dura mater does not adhere to the inner surface of the spinal bones as a periosteum. On the contrary, it is separated from it by a soft unctuous fat mixed with very numerous veins. It adheres pretty closely to the anterior common ligament which intervenes between it and the bodies of the vertebræ, and seems to be continued from the cranial dura mater at the foramen magnum as a funnel-shaped process of that membrane adapted to the shape of the spinal canal. It ends in a blunted extremity in the sacral canal, and is tied down in that situation by certain filiform processes, of which the central one is attached to the coccyx. The spinal dura mater is evidently much more capacious than is necessary merely to contain the spinal cord, and therefore it generally has a loose and flaccid appearance. During life it is kept tense by the fluid which surrounds the cord. The dimensions of the canal of the dura mater vary with those of the spinal canal. It is wider, therefore, in the neck and loins, and narrow in the back. In the lumbar and sacral region it forms a wide sac around the leash of nerves called *cauda equina*.

The dura mater, in both cranium and spine, exhibits numerous perforations for the transit of nerves from the contained centre to the peripheral parts. In the spinal region each of these perforations is subdivided, by a vertical slip of the membrane, into two foramina, which correspond to the anterior and posterior roots of the spinal nerves, and extend on each side down to the lower part of the sacral region.

The blood-vessels of the dura mater are very numerous. Those of the cranial membrane communicate freely with those of the bones. Hence, when separated from the cranium, the external surface of the dura mater has a rough appearance from the number of blood-vessels which have been torn. This membrane derives its supply of

nterior blood from the ophthalmic and ethmoidal arteries in front; n the middle, from the internal maxillary artery by the *middle eningeal*, which enters the cranium by the foramen spinosum, nd by small branches from the internal carotid, called the *inferior eningeal* arteries. Posteriorly the vertebral, the occipital, and the scending pharyngeal supply branches which go by the name of *posrior meningeal arteries*. The arteries of the spinal dura mater ome from the deep cervical, the occipital, and the vertebral, in the ervical region, from the intercostals in the back, and from the lumar arteries in the loins. These vessels pass in at the vertebral foraina, and send branches to the bones as well as to the spinal memranes.

The veins of the dura mater in the cranium constitute a remarkble portion of the vascular system of that cavity. The venous adicles collect the blood from the dura mater, and from the bones of he skull; large veins are formed on the former membrane, and disinct canals in the osseous diploë, figured at pages 110 and 111. These ll tend to certain venous channels, rigid canals, formed by the separation of two layers of the dura mater, which are lined by processes f the inner membrane of the venous system, and are so placed as to ollect the blood from all parts of the cranium. These canals, *sinuses f the dura mater*, receive likewise the venous blood of the brain. The largest sinuses are the *superior longitudinal* and the *lateral inuses*. The former extends along the convex edge of the falx cereri, commencing very small by receiving veins from the ethmoid and rontal bones, and terminates in a reservoir common to it and other inuses at the internal occipital protuberance (*torcular Herophili*). It hus serves to collect blood from the superior and lateral parts of he dura mater, from the vault of the cranium, and from the hemipheres of the brain; the veins of the latter entering it obliquely forwards. The *lateral* sinuses are lodged in tortuous furrows, which mark the occipital, the parietal, and the temporal bones. They are wo in number, and extend on each side from the torcular Herophili to he jugular foramen, where they are continued into the internal jugular veins. These sinuses serve not only to carry into the jugular veins ll the blood which is poured into the torcular, but likewise to receive lood from the lateral and posterior parts of the dura mater and craium, from the inferior surface of the posterior lobes of the brain, and rom the cerebellum. A short sinus, also of considerable width, is odged in the tentorium cerebelli. This is the *straight sinus;* it passes rom before backwards, occupying about the middle of the vault of he tentorium, and opening behind into the torcular. It receives blood rom the interior of the brain by two large veins, the *venæ magnæ Geleni*. The *cavernous sinuses*, two in number, lie one on each side of the sella Turcica, from which the internal carotid arteries separate hem. Their irregular shape is rather that of reservoirs than of canals. They receive the ophthalmic veins from the orbit, as well as numerous small veins from the cranial bones, the dura mater, and the nterior and middle lobes of the brain.

Other small sinuses are met with which serve chiefly to establish a communication between those above mentioned, while at the same time they receive some blood from the neighbouring textures. The *petrosal* sinuses, two on each side, superior and inferior, pass between the cavernous and lateral sinuses: the *transverse* sinus runs between the petrosal and cavernous sinuses of opposite sides; and the *circular* or *coronary* sinus, while it receives blood from the pituitary body and from the sphenoid bone, connects together the cavernous sinuses in front, and thus completes the venous circle around the sella Turcica.

We see, in this arrangement of venous canals, a beautiful provision against the effects of undue venous congestion within the cranium, insured not merely by the inextensible nature of the principal venous canals, but also by the free anastomosis that exists between them, and by the numerous points at which they communicate with the veins of the cranium, and through these with the superficial veins of the scalp.

The spinal veins are extremely numerous and complicated. A very intricate venous plexus surrounds the dura mater on its lateral and posterior surfaces, imbedded among the lobules of soft fat by which the exterior of that membrane is invested. This plexus, less intricate in the dorsal than in the cervical and lumbar regions, communicates very freely with a plexus of veins which surrounds the exterior of the vertebral laminæ and processes (the *dorsi-spinal veins* of Dupuytren). In front of the dura mater, and situate between the outer edge of the posterior common vertebral ligament and the pedicles of the vertebræ, we find two remarkable venous sinuses which extend the whole length of the vertebral column from the occipital foramen to the sacrum. They are the *longitudinal spinal sinuses* of Willis. In calibre they present many inequalities, being dilated at one part and constricted at another, according to the number and size of the vessels which communicate immediately with them. The sinuses of opposite sides are parallel to each other, and communicate by transverse branches, which pass beneath the posterior common ligament. These transverse branches are of variable calibre, like the sinuses themselves, and are dilated at their middle; at which point they receive veins which emerge from the spongy texture of the bodies of the vertebræ (*basi-vertebral veins* of Breschet).* At the highest part of the vertebral canal, the spinal sinuses communicate with the internal jugular veins; in the neck, they communicate with the deep and superficial vertebral veins; with the intercostal veins in the dorsal region, and with the lumbar ones in the loins.

The *arachnoid* is the serous membrane of the cranio-spinal cavity. By its parietal layer it adheres to the dura mater, both of the cranium and spine, and by its visceral layer to the brain and spinal cord, with the intervention of the pia mater. The space between these two layers is the *arachnoid cavity*. In most regions an interval exists between the visceral layer of the arachnoid and the pia

* See his very beautiful illustrations of the venous system.

:r, which is called the *sub-arachnoid cavity*. This space may be onstrated by driving air or coloured liquid beneath the visceral r of the arachnoid. In the spine the connection of the arachnoid pia mater is very loose, being effected by some long filaments ibrous tissue, which interlace slightly, and are most abundant in cervical region. Along the posterior surface of the spinal cord, ie middle line, the sub-arachnoid space is divided by means of a um, which is probably only a modified portion of the tissue of the mater. This septum is most perfect in the dorsal region, but in lumbar and cervical regions it is cribriform, and in some parts is difficult of demonstration. Dr. Sharpey regards it as the reflec- along the median line of a serous membrane, which he supposes ne the sub-arachnoid cavity. Did such a membrane exist, we ld find an epithelium, which, however, we have sought for in

he connection of the arachnoid to the subjacent pia mater is not ose in the head as in the spine. On the superior and lateral sur- s of the brain, where the convolutions are most prominent, the sion is very close, but opposite the sulci between the convolu- s the pia mater recedes from the arachnoid and sinks to the bot- of each fissure, leaving large areolæ in which fluid may accumu- Along the fissure of Sylvius, at the base of the brain between cerebellum and the posterior surface of the medulla oblongata, between the posterior edge of the corpus callosum and the supe- surface of the cerebellum, the arachnoid and pia mater are very ely connected, so that at these situations spaces are found which favourable for the accumulation of fluid.

he cerebro-spinal fluid.—This fluid, which fills the sub-arachnoid e during life, keeps the opposed surfaces of the arachnoid mem- e in intimate contact. Its quantity, which varies between two ten ounces, is in the inverse ratio of the bulk of the brain and al cord. Thus it is most abundant in old persons in whom these ns have shrunk, and it accumulates in cases of deficiency of any ion of them from malformation or disease. Its presence seems ssary to the healthy action of the nervous centres, for the removal t in dogs by Majendie caused considerable disturbance of their tions, probably by favouring distension of the blood-vessels. It iowever, capable of being regenerated as quickly as the aqueous our of the eye, and its reproduction restores the nervous centres ieir natural state. When removed from the body a few moments death, this fluid is, according to Majendie, remarkably limpid; s a sickly odour and a saltish taste, and is alkaline, restoring the ur of reddened litmus.

he cerebro-spinal fluid is most probably secreted by the pia :r, since it is found wherever that membrane and sufficient space t. The ventricles of the brain contain a secretion of very similar, it identical characters, which Majendie describes as communicat- with that of the sub-arachnoid space through an orifice at the rior extremity of the fourth ventricle. This, however, is extremely

doubtful, as the fluid of the ventricles is enclosed by a proper membrane which lines their cavity.

The cerebro-spinal fluid obviously affords mechanical protection to the nervous centres which it surrounds. The interposition of a fluid medium between them and the walls of the cavities is well adapted to guard the former against shocks communicated from without. Its accumulation at the base of the brain is highly favourable for the protection of the large vessels and nerves situate there.

The *pia mater* is the immediate investing membrane of the brain and spinal cord. It is composed of white fibrous tissue and blood-vessels. The former is most abundant in the pia mater of the cord, the latter are most numerous in that of the brain. The principal distinction, therefore, between the spinal and cerebral pia mater is as regards strength and thickness; the spinal being dense and strong, the cerebral being very delicate, almost wholly composed of minute blood-vessels, which are accompanied by white fibrous tissue in small quantity. The spinal membrane forms a complete sheath to the cord, and sends in processes which dip into its anterior and posterior median fissures. It is continuous with the neurilemma of the roots of the nerves on each side. At the inferior extremity of the cord it tapers and terminates in a thread-like process (*filum terminale*) which is inserted into the inferior extremity of the dura mater. Superiorly it gradually diminishes in density as it passes over the medulla oblongata to the cerebral and cerebellar hemispheres. To the surface of these it adheres closely, and innumerable minute blood-vessels pass from it into the nervous substance. It sinks into all the sulci and fissures, and passes into the lateral, the third and fourth ventricles. In the lateral and fourth ventricles it forms projecting processes or folds, somewhat fringed, highly vascular, and invested by epithelium derived from the membrane which lines the ventricles. These processes are called the *choroid plexuses*. Into the third ventricle it sends a lamellar fold of triangular shape (*velum interpositum*), which forms a roof to that cavity and supports the fornix.

Attention has lately been directed to some minute sandy particles, globular in shape, which are frequently connected with the minute vascular ramifications of the internal pia mater. They are found chiefly in the choroid plexuses, and in that portion of the velum which invests the pineal gland. This sabulous matter is composed of phosphate of lime, with a small proportion of phosphate of magnesia, a trace of carbonate of lime, and a little animal matter. (*Van Ghert de pelxubus choroideis.*)

Of the ligamentum dentatum.—This remarkable structure, found in the sub-arachnoid space, requires a brief notice. It seems to be a process of the pia mater, which exhibits more of the glistening appearance of white fibrous tissue than the rest of that membrane. It extends from the occipital foramen to the filiform termination of the pia mater, adhering by its inner straight border to that membrane, and attached on the other hand to the dura mater by a series of dentated processes which penetrate the visceral and parietal layers of arachnoid,

pinning them, as it were, down to the fibrous membrane. They form a vertical septum between the anterior and posterior roots of the spinal nerves. The dentated processes vary in number from eighteen to twenty-two. The first is attached to the dura mater which covers the occipital foramen just behind the vertebral artery; the rest are inserted between the orifices for the exit of the spinal nerves, and the last is on a level with the first or second lumbar vertebra. A considerable quantity of yellow fibrous tissue exists in this structure, especially in its dentated processes.

The *Pacchionian glands* or bodies are whitish granules, composed of an albuminous material, which are found among the vessels of the pia mater, on the edges of the cerebral hemispheres, which push the arachnoid before them, and even project into the longitudinal sinus. They do not occur in the earliest periods of life, and are frequently absent even at the more advanced ages, but they are so often met with in the brains of adult and old persons that many anatomists regard them as normal structures.

Of the Spinal Cord.—The spinal cord is somewhat cylindrical in shape, slightly flattened on the anterior and posterior surfaces. Its anatomical limits are, the occipital plane above, and a point ranging in different subjects between the last dorsal and second lumbar vertebra below. It tapers to its inferior extremity, which lies concealed among the leash of nerves which comes off from its lumbar region, the *cauda equina*. Superiorly the spinal cord is separated from the medulla oblongata by the decussating fibres of the anterior pyramids.

In the cervical and lumbar regions the cord exhibits distinct swellings, of which the cervical is the larger. The cervical swelling extends from the third cervical to the third dorsal vertebra, the lumbar one commencing about the ninth or tenth dorsal vertebra, and not extending beyond the space corresponding to two vertebræ. These enlargements correspond to the situations at which the large nerves to the extremities emerge, in conformity with a law that the physical development of any portion of the cord is in the direct ratio of the sensitive and motor power of the parts which it supplies with nerves.

The spinal cord is divided along the median plane by an anterior and posterior fissure into two equal and symmetrical portions, of which one may be called the *right*, the other the *left* spinal cord. A transverse bilaminate partition, extending throughout the entire length of the cord, separates these fissures, and serves to unite its lateral portions. This partition is composed of a vesicular or gray and a white or fibrous lamina or *commissure*, the gray being situate posteriorly. When examined in a transverse section, the anterior fissure appears evidently wider but of less depth than the posterior; it is penetrated by a distinct fold of pia mater; its floor is formed by the white commissure, which has a cribriform appearance, from being perforated by numerous blood-vessels. The posterior fissure is much more delicate than the anterior, and about the middle of the cord its existence may be doubted; its depth, in the upper part of its course, is equal to fully

16

one half of the thickness of the cord. A single, very delicate layer of pia mater enters it and penetrates to its floor, which is formed by the gray commissure.

On further examination of a transverse section of the cord, we observe that the interior of each half of it is occupied by vesicular matter, disposed somewhat in a crescentic form. The concavity of this crescent is directed outwards: its anterior extremity, or *horn*, is thick, but its margin has a dentated or stellate appearance, which is very distinct in some situations. The gray matter is prolonged backwards in the form of a narrow horn, which reaches quite the surface of the cord, near which it experiences a slight enlargement. This enlargement appears to consist of a gray matter, paler and softer than that of the remainder of the crescent, which has been distinguished by Rolando as *substantia cinerea gelatinosa*, surrounded by a layer of reddish-brown substance (see fig. 66, D., where the central part of the posterior horn is pale). An exact symmetry exists between the gray crescents of opposite sides, so that the description of one is applicable to the other.

The prolongation of the posterior horn of each gray crescent to the surface divides each half of the cord into two portions. All that is anterior to the posterior horn is called the *antero-lateral column:* and this comprehends the white matter forming the sides and front of that half of the cord, limited in front by the anterior fissure, and posteriorly by the posterior horn. The *posterior* column is situated behind the posterior horn of gray matter, and is separated from its fellow of the opposite side by the posterior fissure. The antero-lateral columns are united across the middle line by the anterior or white commissure; the gray crescents, by the posterior or gray commissure; while the posterior columns are not connected, except where the posterior fissure is imperfect or deficient.

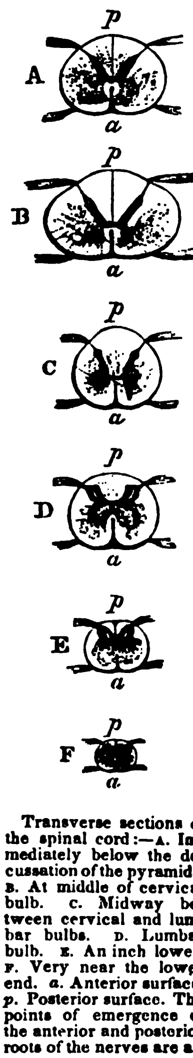
In the different regions of the cord great variety exists as regards the quantity of gray and white matter, and the disposition of the lateral portions of the former. There seems to be a much greater proportion of gray matter to white in the lumbar, than in the cervical or dorsal region of the cord. In the cervical region the crescentic portions are small, and the white matter is abundant. That portion of the white substance which is placed between the posterior gray horns, is augmented by the existence of two small columns (*posterior pyramids*), which extend from the medulla oblongata into this region. In the dorsal region the gray matter is at its minimum of development, and the white matter is likewise small in quantity. The diminution in the quantity of the latter appears more striking as affects the antero-lateral, than the posterior columns. In the lumbar region both the horns of the gray matter are manifestly thicker, and the stellate character of the anterior horn is well marked. Towards the inferior extremity of the cord the white matter appears gradually to cease, leaving the gray to form the principal constituent, until in the commencement of the filiform process it is found alone (fig. 66).

The roots of the spinal nerves emerge from the cord on each side

ro lines which are separated by the ligamentum dentatum. terior line corresponds to the margin of the posterior horn of tter, the anterior one is placed about midween it and the anterior fissure. When of the nerves have been carefully retheir points of emergence are indicated series of foramina in linear sequence on e, but there is no appearance of fissures situations. The roots of the nerves pehe substance of the cord, and are chiefly, ntirely, connected with the antero-lateral

brous matter of the cord consists of some hich pass in a longitudinal direction, e chiefly superficial or contained in the columns, and of others which are oblique erse, and are found in the antero-lateral , or in the white commissure, which is composed of such fibres. Among the of the gray matter fibres are found in mbers, the direction of which is pror the most part oblique or transverse, as able portions of them may be seen so when a piece of gray matter, cut ely, is examined under the microscope. y matter of the cord is disposed in two inal columns, the shape of which in the egions of the cord is represented in the ansverse sections (fig. 66). These cotend from the lower part of the medulla a, with the gray matter of which they inuous. The aspect of their surfaces is and inwards. That which looks in- convex, and is united to the corre- surface of the opposite side by the gray ure, which is a vertical plane, with surking directly forwards and backwards. ferior extremity of the cord these columns taper to a point, and coalesce as the tter diminishes.

Fig. 66.

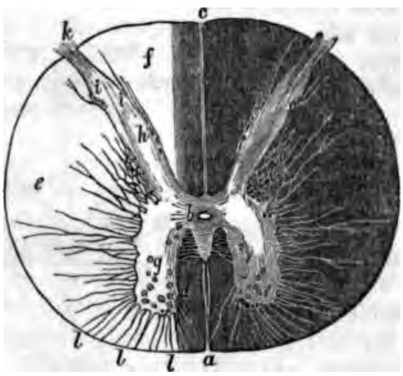


Transverse sections of the spinal cord:—A. Immediately below the decussation of the pyramids. B. At middle of cervical bulb. C. Midway between cervical and lumbar bulbs. D. Lumbar bulb. E. An inch lower. F. Very near the lower end. *a*. Anterior surface. *p*. Posterior surface. The points of emergence of the anterior and posterior roots of the nerves are also seen.

te and spherical vesicles, imbedded in al granular matrix, exist in the gray f the cord at all situations, in the horns as in the commissure. The caudate are most numerous and distinct in the anterior horn, and at of the posterior one. The rest of the posterior horn and inous substance resemble very closely in structure the gray f the convolutions of the brain. When very thin transverse are examined with low powers, a good general view of the disposition of the gray and white *columns* is obtained, but

we gain no satisfactory information as regards the relation of the *elements* of these columns (fig. 67). Stilling and Wallach's plates accord generally with the results of our own examinations, but we cannot admit the accuracy of their interpretation of some of the appearances which they have witnessed and delineated.

Fig. 67.



Transverse section of human spinal cord, close to the third and fourth cervical nerves; magnified ten diameters, (from Stilling:)—*f*. Posterior columns. *ii*. Gelatinous substance of the posterior horn. *k*. Posterior root. *l*. Supposed anterior roots. *a*. Anterior fissure. *c*. Posterior fissure. *b*. Gray commissure, in which a canal is contained, which, according to these writers, extends through the length of the cord. *g*. Anterior horn of gray matter containing caudate vesicles. *e*. Antero-lateral column (from *k* to *a*).

In such a section as that just described, the distinction of gray and white matter is very obvious. From the surface of each horn of the former several lines, of the same colour and general appearance as the central mass, pass, in a radiating manner, towards the surface of the cord and to the surface of the fissures (fig. 67). These lines, according to Stilling and Wallach, are continuous with the roots of the nerves, and are nerve-tubes proceeding from the gray matter to form these roots. Their existence, however, in sections made in situations intermediate to the points of emergence of the nerves, shows that this explanation cannot be the true one. Moreover, they radiate over a surface much more extensive than that from which the roots take their rise, and several pass to that part of the surface of the cord which bounds the fissures, and from which it is impossible that they could reach the point of emergence of either root to contribute to its formation. It is not improbable, however, that they may be processes of the gray matter prolonged toward the surface, to which blood-vessels may pass from the pia mater.*

We observe in the gray matter numerous nerve-tubes of various size passing among its elements in different directions. Besides these, the branching processes from the caudate vesicles are found here: these processes differ from the nerve-tubes in the absence of the white substance of Schwann, in their grayish colour, in their branching, and in a certain minutely granular texture. Numerous extremely minute fibres, perfectly transparent in texture, may be traced to be continuous with the finer subdivisions of these processes (fig. 56, p. 198). Fibres of the same appearance are occasionally found among the tubes of the white substance of the spinal cord; their connection with those of the gray matter is unknown.

* Mr. Smee has lately exhibited to us some well-injected preparations, in which these lines are shown to contain vessels.

Capillary blood-vessels are met with in great numbers ramifying the gray matter. They are much more numerous in this than in : white matter, and the observer should be careful not to confound : most minute of them with some of the fibrous elements above de-ibed.

So far as our present knowledge of the minute anatomy of the nal cord extends, it is favourable to the supposition that the spinal rves derive their origin, at least partly, from the gray matter. The igitudinal fibres of the cord may consist in part of fibres continuous th those of the brain or cerebellum, and in part of commissural res, serving to unite various segments of the cord with each ier, or to connect some part or parts of the encephalon with them. iose fibres which may be regarded as strictly spinal are probably lique in their course, forming their connection with gray matter at oint higher up in the cord than that at which they emerge from surface, and may be readily confounded with the longitudinal res when their course is long. Other oblique or transverse fibres bably do not emerge from the cord, but connect the segments opposite sides, forming a transverse commissure. So that four sses of fibres, each different in function, may be considered to ex-in the cord. 1. *Spinal fibres*, oblique or transverse, which pro-gate nervous power to or from the segments of the cord itself. *Encephalic fibres*, longitudinal, the paths of volition and sensation, iich connect the spinal cord with the various segments of the en-phalon. 3. *Longitudinal commissural fibres*. 4. *Transverse com-ssural fibres*.

Of the encephalon.—The brain or encephalon is that mass which contained within the cranial cavity. The plane of the occipital amen separates it from the spinal cord, inasmuch as that plane uld about pass through the inferior extremity of the medulla ob-gata.

Four segments are obviously distinguished in the encephalon. 1. e *medulla oblongata*. 2. The *cerebrum*. 3. The *cerebellum*. Some res of the medulla oblongata extend to the cerebrum, and some to e cerebellum. The fourth segment, which is called the *mesocephale*, ntains fibres passing between all the rest, as well as some connect-g opposite sides. This constitutes a sort of conflux to the segments ove named, and may be compared to a railway terminus, at which veral lines meet and pass each other.

The brain of the adult man weighs about 50 oz., or a little more n 3 lbs. avoirdupois.* This great weight depends mainly upon the rebrum and cerebullum, the medulla oblongata and mesocephale ming not more than one-tenth of the whole weight. These parts ist in their highest state of development in man. Their size does t appear to be regulated by the physical development of the body, her in man or in the lower animals. Thus the horse, although eatly exceeding the human subject in the size of his body, has a

* See Reid's Tables. Lond. and Edinb. Monthly Journal of Med. Science. April, 3.

brain considerably inferior. The largest brain of a horse weighs, according to Sœmmering, 1 lb. 7 oz., but the smallest adult human brain may be estimated at 2 lbs. 5½ oz. Many other instances might be cited, of animals of great bulk, with brains weighing considerably less than that of man. The brains of the elephant and the whale, however, although inferior to it in general organization, are absolutely heavier than that of man. That of an elephant, dissected by Sir Astley Cooper, had a weight of 8 lbs. 1 oz.; and Rudolphi found the brain of a whale, 75 feet long, (*Balæna mysticetus*,) to weigh 5 lbs. 10¼ oz. Yet how inferior must be the development of the brain in these stupendous animals relatively to the whole body, if, with their enormous superiority of bulk, their brains exhibit so little excess of weight over that of man!

Even among men there does not appear to be any fixed relation between the bulk of the body and that of the brain. A large man has by no means necessarily a large brain, and it often happens that persons of small stature have the brain above the average size. In women the brain is generally lighter than in men. Dr. John Reid assigns an average difference of 5 oz. 11 dr. in favour of the male brain. Yet this difference is scarcely proportionate to the general inferiority of organization and of size of the female to the male.

It is impossible to explain the great superiority of the human brain, both in organization and in the absolute quantity of nervous matter which it contains, without admitting its connection with the mind, and the influence exerted upon its nutrition and growth by that immaterial principle. The men of greatest intellectual power are those who possess the largest brains. Cuvier's brain, as stated by Tiedemann, weighed 4 lbs. 11 oz. 4 dr. 30 grs. troy; and that of Dupuytren 1 oz. 4 dr. 30 grs. less. On the other hand, the brain of an idiot weighs scarcely more than that of the horse mentioned above. Tiedemann found the brain of an idiot, fifty years old, to weigh 1 lb. 8 oz. 4 drs.; and that of another, forty years old, 1 lb. 11 oz. 4 drs. In advanced age, when the mental faculties have declined, the brain generally experiences a decrease of size; there are many, however, who preserve their intellectual vigor to a very advanced period of life, and in such persons, doubtless, the brain does not exhibit any evidence of shrinking. It is during the period of greatest mental activity and power that the brain acquires and maintains its highest point of development, that is, between the ages of twenty and sixty.

Whilst there is an evident connection between a large *quantity* of cerebral matter, and a highly developed intellect, the *quality* of the mind and that of the brain substance may also be supposed to have a close relation to each other. For great power of action a *large* muscle is needed, but for vigorous and well-adjusted muscular movement a certain *quality* of fibre is also necessary to give full scope to the nervous power (see pp. 175–7–79). It is impossible to determine what this peculiarity in quality is, but some idea of the great influence which it may possess in the exercise of the two great vital forces, the *muscular* and *nervous*, may be gained from comparing the energy and

action of a well-bred horse with those of one which, in the language of the turf, shows little or no breeding. The actual amount of muscular or nervous fibre may be the same in both, or it may be less in the horse of good breeding than in the other, yet the former does his work and endures fatigue better.

The nature of the connection between the mind and nervous matter has ever been, and must continue to be, the deepest mystery in physiology; and they who study the laws of Nature, as ordinances of God, will regard it as one of those secrets of his counsels "which Angels desire to look into."* The individual experience of every thoughtful person, in addition to the inferences deducible from revealed Truth, affords convincing evidence that the mind can work apart from matter, and we have many proofs to show that the neglect of mental cultivation may lead to an impaired state of cerebral nutrition; or, on the other hand, that diseased action of the brain may injure or destroy the powers of the mind. These are fundamental truths of vast importance to the student of mental *pathology* as well as of physiology. It may be readily understood that mental and physical development should go hand in hand together, and mutually assist each other; but we are not, therefore, authorized to conclude that mental action results from the physical working of the brain. The strings of the harp, set in motion by a skillful performer, will produce harmonious music if they have been previously duly attuned. But if the instrument be out of order, although the player strike the same notes, and evince equal skill in the movements of his fingers, nothing but the harshest discord will ensue. As, then, sweet melody results from skillful playing on a well tuned instrument of good construction, so a sound mind, and a brain of good development and quality, are the necessary conditions of healthy and vigorous mental action.

Medulla oblongata.—Of the segments of the encephalon above enumerated, the medulla oblongata is that which is more immediately connected with the spinal cord, and through which the brain is brought into communication with the other vital organs and with most of the peripheral parts. It is, therefore, truly "the link which binds us to life." In form and general anatomical characters, it very much resembles the spinal cord, with which it is continuous, standing in the same relation to it as the capital to the shaft of a column.

In the sense in which we here speak of it, the medulla oblongata is limited above by the mesocephale; but its constituent fibres extend beyond that segment, and form important connections with the rest of the brain. It is completely contained within the cranial cavity, its lowest part being just above the level of the plane of the occipital foramen.

The size of the medulla oblongata is in the direct ratio of that of the nerves which proceed from it. Hence it is very much larger, both

* The admirable chapter in Bp. Butler's Analogy "Of a Future Life," cannot be too attentively studied in reference to this subject.

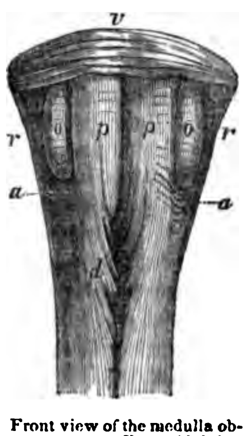
absolutely and relatively, in some of the lower animals than in man: in many of them it forms the largest of all the segments of the encephalon, while in man it is much the smallest.

In the medulla oblongata there is the same symmetry of arrangement which we have noticed in the cord. An anterior and posterior fissure divide it into two equal and symmetrical portions. The posterior fissure is deep and narrow, and is continuous with that of the cord. The anterior fissure is wider and less deep, and is separated from the same fissure of the cord by certain fibres which cross obliquely from each side in its lower third, decussating each other. These fibres are called the *decussating fibres* of the anterior *pyramids*, and form, very fitly, an anatomical demarkation between the medulla oblongata and the spinal cord.

The floor of the anterior fissure is formed by a layer of fibrous matter which is rendered cribriform by the orifices of the numerous bloodvessels which penetrate it. This constitutes a commissure of transverse fibres, similar to that described in the spinal cord. The posterior fissure extends to the posterior surface of this commissure, there being no such transverse lamina of vesicular matter in the medulla as in the cord.

When the pia mater has been carefully removed from the surface of the medulla oblongata, certain grooves are seen which indicate a subdivision of the organ, which is convenient for the purposes of description. In front are the *anterior pyramids* (*corpora pyramidalia antica*) separated from each other along the middle line by the anterior fissure. External to each anterior pyramid there is an oval prominence surrounded by a superficial groove, which in some instances is partially interrupted by some *arciform fibres* which cross it at its lower part. These projections are the *olivary bodies*. External to these, and forming the lateral and a great part of the posterior region of the medulla oblongata, are the *restiform bodies*, two thick columns of fibrous matter, which are separated from each other along the middle line by two slender columns, *the posterior pyramids*. These last bound the posterior fissure.

Fig. 68.



Front view of the medulla oblongata:—*p*, *p*. Pyramidal bodies, decussating at *d*. *o*. *o*. Olivary bodies. *r*, *r*. Restiform bodies. *a*. *a*. Arciform fibres. *v*. Lower fibres of the Pons Varolii.

The *anterior pyramids* are bundles of fibrous matter which extend between the antero-lateral columns of the cord and the cerebral hemispheres. Below the mesocephale the fibres are compactly applied to each other so as to form on each side of the median line a column of white matter, the transverse section of which has more or less of a triangular outline. Traced upwards, the pyramids are found to pass into the mesocephale above its inferior layer of transverse fibres, the *pons Varolii*. At its entrance into this part of the brain each pyramid

xperiences a slight but well-marked constriction, but immediately xpands again; and its fibres in their further course upwards grauually diverge, and contribute to form the inferior lamina of the crus erebri.

In their ascent through the mesocephale the fibres of the pyramids re crossed at right angles by some deep transverse fibres on different planes which belong to the same system as those which constitute he pons. With these fibres those of the pyramids interlace. Veicular matter is deposited in the intervals between the more deeply eated fibres, from which probably some fibres take their origin, and join the pyramids at their emergence from the pons, to form the inferior layer of the crus cerebri.

Traced downwards, the fibres of each anterior pyramid pass in greater part *backwards* as well as downwards, sinking into the antero-lateral column of the cord of the opposite side (fig. 68, *d*), whilst a small portion of them, those, namely, which constitute the outer margin of each pyramid, pass to the column of the same side. Other fibres of these bodies do not pass down into the spinal cord at all, but taking a curved course around the inferior extremity of each olivary body they ascend towards the cerebellum, forming the *arciform* fibres. Or, if the description be pursued in an opposite direction, each pyramid may be stated to be composed of some fibres from the antero-lateral spinal column of its own side, and of others which greatly exceed the latter in number, from the antero-lateral column of the opposite side, and it is connected with the restiform body of the same side by the arciform fibres.

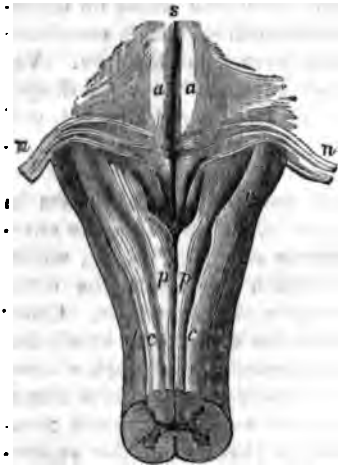
The decussation takes place by from three to five bundles of fibres from each pyramidal body. In separating the margins of the anterior fissure, these fibres are found to interrupt its continuity with the anterior fissure of the medulla oblongata, and, therefore, may be conveniently referred to as a boundary between the medulla oblongata and the spinal cord.

This decussation has great interest in reference to the explanation f the phenomena of diseased brain. It is well known that lesion of one hemisphere of the brain when sufficiently extensive to cause paralysis, will induce that paralysis on the opposite side of the body. And, although a very few exceptions have been recorded, this is so constant that it must be regarded as a law, that the influence of each hemisphere is rather upon the opposite half of the body than on that f its own side. It is not, however, meant that the hemisphere has no influence on the same side of the body. On the contrary, it is most probable that it does exert some influence from the partial connection of each anterior pyramid with the antero-lateral column of the pinal cord on the same side. Now the decussation, above described, bviously suggests an explanation of this phenomenon, which is among he most interesting that anatomy can offer. In confirmation of this tatement it may be remarked, that lesion of one side of the cord, *below* the decussation, affects the same side of the body, and that alone; whilst disease of a paralyzing influence, wherever it occurs *above* the ecussation, affects the opposite half of the body. The exceptions

to this rule are too anomalous and few to invalidate the explanation so long adopted.

The restiform bodies form the lateral and posterior part of the medulla oblongata. They are cylindrical in form. Below they are distinctly continuous with the antero-lateral and posterior columns of the cord. As they ascend, they diverge and leave a considerable space between them, which is the fourth ventricle. Each restiform body passes into the corresponding hemisphere of the cerebellum, forming a considerable portion of the crus, the stalk of fibrous matter around which the hemisphere is formed. These bodies are, therefore, the bond of connection between the cerebellum and the spinal cord, for which reason they have been appropriately designated *processus cerebelli ad medullam oblongatam.*

Fig. 69.



Posterior view of the medulla oblongata: —*pp*. Posterior pyramids, separated by the posterior fissure. *rr*. Restiform bodies, composed of *cc*, posterior columns, and *dd*, lateral part of the antero-lateral columns of the cord. *aa*. Olivary columns, as seen on the floor of the fourth ventricle, separated by *s*, the median fissure, and crossed by some fibres of origin of *nn*, the seventh pair of nerves.

The posterior median fissure is bounded on each side by a small column, not exceeding one-eighth of an inch in breadth. These columns are called the *posterior pyramidal bodies*. Their outer limit and line of demarkation from the restiform bodies is indicated by a superficial groove, along which a separation of the two structures readily takes place, in a preparation previously hardened in spirit.

The *olivary bodies* are oval projections on each side of the anterior pyramids. When the latter have been carefully removed, it may be demonstrated that these bodies are continuous with the central part of the medulla oblongata. They are coated on the outside with fibrous matter, within which is a folded lamella or capsule of vesicular substance, enclosing a white nucleus. By slicing off a layer of this body even with the surface of the medulla, the capsule may be seen disposed as a wavy line, surrounding an oval space of white matter. If examined in transverse section, this wavy line of vesicular matter is still apparent, but it is incomplete behind and within; and the same may be observed on a vertical section of the olivary body. This lamina is called the *corpus dentatum.*

When the pyramids are very largely developed these oval projections on the surface of the medulla oblongata do not appear. Hence the olivary eminences are peculiar to the human subject, and some of the monkeys.

On tracing the olivary bodies downwards, they are found to ap-

roximate towards each other, the anterior pyramids which separate nem gradually diminishing in breadth, and they apparently terminate y becoming continuous with the antero-lateral columns of the spinal ord.

The olivary bodies, though separated from the margin of the pons 'arolii by a distinct depression, may be traced upwards through the nesocephale along with the central substance of the medulla ob-ongata (*fasciculi innominati* of Cruveilhier), forming a considerable ortion of the superior layer of each crus cerebri, and apparently ecoming continuous with the optic thalamus and quadrigeminal odies.

The olivary bodies and the central substance of the medulla oblon-ata may be described as connecting the spinal cord with the quadri-eminal bodies and the optic thalami.

It seems highly probable that the olivary bodies constitute the es-ential portion or *nucleus* of the medulla oblongata; that on which its ower as an independent centre depends. Strong support to this view s derived from the important fact, that these bodies and the central ortion of the medulla oblongata, with which they are directly con-inuous, contain that intermixture of vesicular and fibrous matter which constitutes the main character of a nervous centre.

If this be correct, the anterior and posterior pyramids, and the rest-form bodies, must be regarded as consisting chiefly of fibres which ass from the spinal cord to the cerebrum, or cerebellum, and not ssentially concerned in the formation of the medulla oblongata. The fibres of these bodies are in fact mainly commissural; the an-erior pyramids serving to connect the cerebral hemispheres to the pinal cord, the restiform bodies connecting the cerebellum to it, nd the posterior pyramids being the means of connection posteriorly etween the medulla oblongata and the cervical and dorsal regions f the spinal cord. But the olivary bodies and the central matter of he medulla are directly continuous with certain principal gangliform nasses of the brain, the optic thalami and quadrigeminal bodies, and y their prolongation upwards form a large portion of the crura of the rain.

From the description of the minute structure of the medulla ob-ongata by Stilling, founded upon investigations conducted in the ame way as those on the spinal cord, it would appear that nume-ous transverse fibres pass into the central and posterior part of the nedulla. It is not unlikely that many of these so called fibres *may* e bundles of nerve tubes, but it is also highly probable that many f them are blood-vessels, which pass in great numbers into the cen-ral substance of the medulla. The same mode of connection which xists between the roots of the nerves and the spinal cord, whatever hat may be, will no doubt be found to prevail in the medulla; and s several important nerves emerge from this portion of the ence-halon, it seems very likely that their fibres should penetrate to its entral part to form a connection with its gray matter. This ques-ion, however, is not to be decided by the use of low powers of he microscope, such as Stilling employs; nor have our trials with

higher ones as yet led to any information sufficiently specific to enable us to make a positive statement respecting the points in question. There is nothing in the results of Stilling's researches which does not confirm that which previous dissections, by coarser means of observation, had pointed out—namely, that the restiform and pyramidal

Fig. 70.

Transverse section of the medulla oblongata through the lower third of the olivary bodies. (From Stilling.) Magnified 4 diameters.

a. Anterior fissure. *b*. Fissure of the calamus scriptorius. *c*. Raphé. *d*. Anterior columns. *e*. Lateral columns. *f*. Posterior columns. *g*. Nucleus of the hypoglossal nerve, containing large vesicles. *h*. Nucleus of the vagus nerve. *i, i*. Gelatinous substance. *k, k*. Roots of the vagus nerve. *l*. Roots of the hypoglossal, or ninth nerve. *m*. A thick bundle of white longitudinal fibres connected with the root of the vagus. *n*. Soft column (*Zartstrang*, Stilling). *o*. Wedge-like column (*Keilstrang*, Stilling). *p*. Transverse and arciform fibres. *q*. Nucleus of the olivary bodies. *r*. The large nucleus of the pyramid. *s, s, s*. The small nuclei of the pyramid. *u*. A mass of gray substance near the nucleus of the olives (*Oliven-Nebenkern*). *u, q, r*, are traversed by numerous fibres passing in a transverse semicircular direction. *v, w*. Arciform fibres. *x*. Gray fibres.

bodies are composed in great part of fibres, taking a longitudinal course, while the central portion contains both the vesicular and fibrous nervous elements. The fibres of the latter, according to Stilling, taking chiefly, if not exclusively, a transverse direction.

There is no evidence of any interchange of fibres between the restiform bodies, nor between the posterior pyramids of the right and left sides, such as has been noticed between the anterior pyramids in the description of their decussating fibres. The central or olivary columns of the medulla oblongata, however, have a very intimate connection with each other, along the mesial plane, apparently by fibres passing from one to the other.

When the medulla oblongata is divided vertically along the median plane, a series of fibres is seen to form a septum between its right and left half. These fibres take a direction from before backwards, and appear to connect themselves with the posterior olivary columns. They are limited inferiorly by the decussating fibres. Cruveilhier proposes for them the name *antero-posterior fibres;* they appear to belong to the same system as the arciform fibres.

Of the cerebellum. This segment of the encephalon is situated above and behind the medulla oblongata in a distinct compartment of the cranium, which has for its roof the tentorium cerebelli. It bears to the cerebrum in point of weight about the proportion 1: 8, and to the entire encephalon, 1: 10.

The cerebellum consists of a central and of two lateral portions. The former, also called the *median lobe*, is the primary part; it is the only part of the organ which exists in fishes and reptiles; the lateral portions or *hemispheres* are additions to this, and denote an advance in development. It is in birds that these are first found; they are most highly developed in mammals, and attain their maximum in man.

Upon removing the pia mater from the surface of the cerebellum, we observe its arrangement in numerous thin lamellæ, which are attached to a central column of fibrous matter. A vertical section of either hemisphere serves well to display their structure. A series of planes of fibrous matter become detached from the central white column, each plane separating from it at a different angle. These planes are in number about ten, counting those on the upper as well as the under surface. Those situated in front are detached at a right angle, the posterior ones at an acute angle. Each plane forms the centre of a lobule, and as it proceeds outwards secondary planes are detached from it, and from these again others separate. These secondary and tertiary planes are clothed by a layer of vesicular matter, which also invests the primary planes at the angles of separation from the principal central column.

We have described each primary plane as forming the central portion, or stem of a lobule. Each lobule is circumscribed and separated from those in immediate relation to it, by a fissure which extends to the principal column. The lobules are composed of laminæ which derive their fibrous matter from the central stem.

Thus the substance of each hemisphere of the cerebellum is penetrated by a number of fissures, easily traced by following the pia mater, which lines them. These fissures are divisible into two classes, primary and secondary. The primary penetrate to the principal central column, and isolate the lobules; the secondary separate the lamellæ of which each lobule is composed. The deepest and most remarkable of the former corresponds to the posterior margin of each hemisphere, passing in the horizontal plane forwards and separating the posterior laminæ into a superior and inferior set.

The structure of the median lobe is essentially the same as that of the hemispheres. A stem of fibrous matter, continuous with the *processus cerebelli ad testes*, constitutes the central column, and planes

radiate from it in the same manner as in the hemispheres. Lobules are formed around these planes, and the aggregate of those on the superior surface of the median lobe constitutes what is called the *superior vermiform process;* and that of the inferior ones, the *inferior vermiform process.* The lobules of the median lobe have a distinct continuity of substance with those of the hemispheres on each side, and thus the entire lobe becomes a medium of connection, or a commissure between the hemispheres; nevertheless, the similarity of its structure to that of the hemispheres, and its existence in the animal series without the lateral portions, denote that it exercises an independent function.

Within the central stem of each hemisphere of the cerebellum, the fibrous matter is partially interrupted by a peculiar arrangement of

Fig. 71.

Analytical diagram of the encephalon—in a vertical section. (After Mayo.)
s. Spinal cord. *r.* Restiform bodies passing to. *c,* the cerebellum. *d.* Corpus dentatum of the cerebellum. *o.* Olivary body. *f.* Columns continuous with the olivary bodies and central part of the medulla oblongata, and ascending to the tubercular quadrigemina and optic thalami. *p.* Anterior pyramids. *v.* Pons Varolii. *n. b.* Tubercula quadrigemina. *g.* Geniculate body of the optic thalamus. *t.* Processus cerebelli ad testes. *a.* Anterior lobe of the brain. *q.* Posterior lobe of the brain.

the vesicular substance, called by Vicq d'Azyr *corpus dentatum* (fig. 71, *d*). This is only found in the inner half of the stem, at about a quarter of an inch from the origin of the crus. It may be demonstrated by making a vertical section through the cerebellar hemisphere, leaving two-thirds of its substance to the outside of the section. The surface of the section presents at the situation above described a remarkable layer or capsule of gray matter, surrounding in great part an oval space; the gray layer has an undulating disposition, and is convex towards the surface, but open towards the crus. The precise object of this remarkable structure is not known; but the microscopic investigation of it shows that in it there is a mingling of the elements of the vesicular and fibrous substances.

The central stem, or crus, around which each hemisphere of the cerebellum is developed, is formed by three bundles of fibres, each on a different plane. These are called its peduncles. Through them the cerebellum forms a connection with other parts of the encephalon. The superior layer or peduncle is a bundle of fibres which extends to the corpora quadrigemina, *processus cerebelli ad testes;* the middle layer passes to the medulla oblongata, the *restiform bodies;* and the inferior peduncle consists of transverse fibres (*Pons Varolii*), which pass to the opposite side, and also form a considerable portion of the mesocephale.

Lesions of the cerebellum, when so deep seated as to affect the primary planes of fibrous matter or the central stem, have the same crossed effect as those of the cerebellum. This is not so obviously explicable as the similar instance of the cerebrum, for the cerebellar fibres of the medulla oblongata (restiform bodies) do not appear to decussate. Yet it seems scarcely necessary, in order to explain the phenomenon, to have recourse to the supposition that they do decussate. The close connection between the restiform bodies and the pyramids, by means of the arciform fibres, renders the latter exceedingly liable to sympathise with the condition of the former, and, therefore, prone to propagate the morbid influence to the opposite half of the spinal cord, and through that to the opposite half of the body. It must be borne in mind that some of the fibres of the anterior pyramids very probably derive their origin from the central gray matter of the medulla oblongata, as well as of the mesocephale, and that some, at least, of those which affect the right half of the cord, probably derive their origin from the left side of either or both of those segments of the encephalon. That lesion of one hemisphere of the cerebellum may influence the corresponding half of the medulla oblongata, is likely, from the connection which the restiform fibres establish between them. The connection of the cerebellum with the mesocephale is most clearly established by means of the transverse fibres which constitute the *pons Varolii*.

Respecting the intimate structure of the cerebellum, little is known of a very exact nature. The white stems and plates are fibrous, and consist of multitudes of nerve-tubes of all sizes, which follow the general direction of each stem or plate. These fibres doubtless tend principally to propagate the peculiar influence of the cerebellum to the

spinal cord and the mesocephale. Some probably are commissural, as the processus cerebelli ad testes (or cerebro-cerebellar commissures), the fibres of the pons, and some of those of the median lobe. Mr. Mayo supposes that others pass between the laminæ, but their existence is extremely doubtful.

The vesicular matter which covers the plates contains the ordinary elements, of which, however, the caudate vesicles constitute a principal portion (p. 198). These are so disposed that their processes pass off chiefly towards the circumference, their obtuse extremities being directed towards the laminæ. Besides these, there is in each layer of vesicular matter a thin lamina composed of round clear nucleus-like particles, which cohere to each other without the intervention of any matrix or other connecting substance. Fine nerve-tubes and blood-vessels pass through it. This lamina is intermediate to two which contain nerve-vesicles, one of which is in immediate connection with the fibrous matter of the cerebellum, the other with the pia mater.

Of the fourth ventricle.—The divergence of the restiform bodies in their ascent to the hemispheres of the cerebellum leaves a considerable space, which is of a lozenge shape, having its superior angle towards the brain, its lateral angles towards the cerebellar hemispheres, and its inferior angle at the point of separation of the restiform bodies. Along its floor are seen the central or olivary columns of the medulla oblongata, extending upwards to the optic thalami. A fissure, continuous with the posterior median fissure, separates these columns. Some bundles of white fibres, which may be traced to the soft portion of the seventh pair of nerves, cross these bundles nearly at right angles to them and to the fissure (p. 242), and form with the latter the *calamus scriptorius*, the white fibres constituting the barbs of the pen. The roof of this ventricle is formed in front by the anterior laminæ of the superior vermiform process, which constitute the *valve of Vieussens;* and behind by the inferior vermiform process. A process of pia mater enters it at its inferior angle, just as the choroid plexus penetrates the inferior cornu of the lateral ventricles of the brain. The reflexion of the lining membrane on the process of pia mater seems to close up the ventricle below, and cut off its direct communication with the subarachnoid space. A canal, which passes through the mesocephale, establishes the communication of this with the third ventricle, *iter a tertio ad quartum ventriculum.*

The fourth ventricle properly belongs to the medulla oblongata. It is, therefore, present in all the vertebrate classes, and is, in point of size, directly proportionate to the medulla itself.

Of the mesocephale.—This term, suggested by Chaussier, denotes that this portion of encephalon is the bond of union to the rest, the cerebrum above the medulla oblongata below, and the cerebellum behind.

The inferior surface of the mesocephale, the *pons Varolii*, consists of a series of curved fibres, which pass from one crus cerebelli to the other. When the brain lies with its base uppermost, these fibres ap-

ear to cross over the upward continuations of the anterior pyramids, s a bridge over a stream. Hence the term *pons* was applied to them y Varolius.* The fibres form a series of curves, convex forwards, oncave towards the medulla oblongata, the posterior being much ess curved than the anterior. At either side they become more losely packed, taper, and form the inferior layer of each crus cere-elli. Along the middle line a groove traverses the surface of the ons from its posterior to its anterior margin, in which the basilar rtery usually lies.

The fibres of the pons are always developed in the direct ratio of he hemispheres of the cerebellum. In animals which have only the nedian lobe, there is no pons; and when the hemispheres are small, he pons is small likewise. Hence these fibres must be regarded as specially belonging to the cerebellum, and as serving, whatever other office they may perform, to connect the hemispheres of oppo-site sides. They constitute, therefore, *the great transverse commis-ure of the cerebellum*, and are to the hemispheres of that organ what he corpus callosum is to those of the brain.

These transverse fibres do not form merely a superficial plane, which covers the pyramids in their upward passage: on the contrary, hey extend to more than one-half of the depth of the mesocephale, s is apparent on a transverse section of it. The more superficial ibres simply cross from one side to the other; the deeper-seated ones nterlace with those of the pyramids. The fibres are irregularly dis-osed in planes, and vesicular matter is interposed between the more leeply-seated ones. From this gray matter it is not improbable that ome of the fibres of the pyramids may take origin.

On the superior surface of the mesocephale are the quadrigeminal odies, (*nates* and *testes*,) and beneath these the olivary columns. A light longitudinal groove separates the quadrigeminal bodies into a ight and left pair, and a transverse groove indicates their division nto an anterior and posterior pair. They are gangliform bodies, of a grayish white colour, containing fibrous and vesicular matter. The anterior (*nates*) are somewhat elliptical in shape; they are the arger in man. The posterior (*testes*) are hemispherical, and some-what lighter in colour. These bodies are much more developed in he lower animals than in man. In mammalia only do they exist as our. In birds, reptiles, and fishes, they are only two in number, and are called *optic lobes*, from their connection with the optic nerves. They are hollow in these classes, but in mammalia they are solid.

Between each testis and the corresponding hemisphere of the erebellum, a band of fibrous matter extends—*processus cerebelli ad estem*. Each band may be traced into the crus cerebelli of the same ide, of which it forms the superior layer, so that its fibres are doubt-ess continuous with some of those which form the white plates of he median and lateral lobes. The connection of these processes with the testes is more apparent than real. They seem rather to pass eneath them to the optic thalami; and, therefore, it has been justly

* The terms *annular protuberance, isthmus, encephali, nodus encephali,* are also fre-uently used.

remarked, they might be more appropriately named *processus cerebelli ad cerebrum*. The valve of Vieussens occupies the interval between these processes. This layer evidently results from the spreading out of some of the anterior lamellæ of the superior vermiform process.

From the preceding description, it will appear, as before stated, that the stem of fibrous matter which forms the crus cerebelli derives its fibres from, or is continuous with, three planes of fibrous matter; the highest, or most superficial, being the processus cerebelli ad testem; the second, or middle, the restiform body; and the inferior the fibres of the pons. By the first, the cerebellum and cerebrum are connected; by the second the cerebellum is connected with the medulla oblongata; and by the third, each hemisphere is brought into union with its fellow, and with the mesocephale. Foville assigns other fibres as constituents of the crura cerebelli, which he describes as expansions connected with the fifth and auditory nerves.

The crura cerebelli seem to emerge from the postèrior angles of the mesocephale. From its anterior part there proceed upwards, with a slight divergence, two similar processes, of considerable thickness, which enter each hemisphere of the brain, and upon which each of those masses rests, as a mushroom upon its stalk.

A septum of a similar kind to that described in the medulla oblongata is found in the mesocephale. The fibres derived from the superficial layer of the pons pass backwards from the median groove to the posterior and superior part of the mesocephale.

Of the cerebrum.—The constitution of each *crus cerebri* may be best understood by examining a transverse section made a little beyond its emergence from the mesocephale. Upon the surface of such a section three planes of nervous matter may be distinctly observed. The inferior one is composed of fibrous matter, continuous below with that of the mesocephale, and the anterior pyramids, and which passes upwards to the corpus striatum. Immediately above it is a remarkable mass of a peculiarly dark, almost black, matter, which constitutes the well-known *locus niger* of the crus cerebri. It contains large caudate vesicles, abounding in pigment, with nerve fibres passing among them, or originating from them. This black layer does not extend beyond the crus. It forms a partition between the inferior or fibrous layer, and a superior one, which composes the principal portion of the crus. This consists of a grayish matter, continuous with the central portion of the medulla oblongata, or the olivary columns, and passes into the optic thalami.

The *optic thalamus* and *corpus striatum* are large ganglia formed upon the anterior and upper extremity of each crus, and with which the nervous matter of its upper and lower planes appears to be intimately connected. The *optic thalamus* is manifestly continuous with the superior plane, or olivary columns: its colour and texture are quite of the same nature with those of that plane; and when a longitudinal section of it is carried down through the mesocephale and medulla oblongata, no distinction is apparent between the ganglion and the olivary column, so complete is the continuity of texture. The colour of these bodies has been not inaccurately compared to that

coffee largely diluted with milk (*café au lait*). This arises from ie intermixture of vesicular matter with a very close interlacement f fibres.

The *corpus striatum* has a much darker colour than the optic ialamus. When a section of it is made in an oblique direction, pwards and outwards, it exhibits the striated appearance whence s name is derived. This arises from the passage of the fibres of the iferior layer of the crus into the vesicular matter of the ganglion. he fibres do not at first blend with the vesicular matter, as in the ialamus, but are collected into bundles, which are large at their en-ance from the crus, but subdivide into much smaller ones, diverg-ig from each other, and radiating through the ganglion in various irections, upwards, forwards, outwards, and backwards.

When thin sections of the corpus striatum are examined by trans-iitted light, the smallest bundles of fibres observable in them appear consist of tubules reduced to their minutest dimensions, and closely nited to each other. So compactly applied are they, that very little ght passes through or between them. Hence they appear to be dark iasses lying in the substance of the ganglion, and, from their opa-ity, it is very difficult to determine their exact relation to the ele-ients of the vesicular matter. Many of the bundles, however, ppear to us to attach themselves, at different parts of the ganglion, s if around a large vesicle of which, with its nucleus, we have ometimes seen indications at one extremity of the dark mass of ggregated fibres. Other bundles of fibres appear to emerge from ie corpus striatum, and to contribute to form the fibrous matter of ie hemisphere.

If this view of the structure of the corpus striatum be correct, it rould appear, that while a large proportion of the fibres which con-titute the inferior layer of the crus penetrate that ganglion, many of iem do not pass beyond it. They may be described as terminating i it—or, more properly, if traced from above, as taking their origin r point of departure from it. Many of the fibres which seem to ass from the corpus striatum into the white matter of the hemisphere re doubtless similarly related to the former body, *i. e.*, take their ise from the vesicular matter, or, to speak more exactly, pass be-ween the vesicular matter of the hemisphere and that of the corpus triatum. It is also highly probable that some fibres pass completely hrough the corpus striatum.

Thus, three sets of fibres may be described as existing in the cor-us striatum; 1st, those which below enter into the formation of the rus, and above are connected with that ganglion; 2dly, those which re connected inferiorly with the corpus striatum, and above with he cerebral convolutions; and lastly, those which pass from the rhite substance of the hemispheres through the corpus striatum to he crus cerebri. And of these three sets of fibres, the first serves o connect the corpora striata with the mesocephale and medulla ob-ongata; the second to connect the cerebral convolutions with the orpora striata; and the third to connect the convolutions with the iesocephale and medulla oblongata. It must be confessed, however,

that the evidence upon which the existence of the third class of fibres rests is less satisfactory than that for the first and second, although most of those anatomists who are contented with coarse dissection seem to recognize only the third class.

The fibres of the optic thalamus are doubtless, also, continuous with some of those which form the white matter of the hemispheres; and from the intimate manner in which this body is embraced by the corpus striatum, and the close connection which exists between them, there can be but little doubt that fibres pass from the one to the other.

Projecting from the external and posterior part of each optic thalamus, there are two small gangliform masses, similar in colour and in structure to that body. These are the *corpora geniculata*, *externum* and *internum* (fig. 71, *g*). Some fibres of the optic tracts appear to form a connection with them. By a transverse section through either geniculate body into the substance of the thalamus, the distinctness of the former may be demonstrated.

A fissure which exists between the optic thalami is called the *third ventricle*. Its roof is formed by the *velum interpositum*, one of the principal internal processes of the pia mater. It contains a bridge of soft grayish matter, extending from one optic thalamus to the other. This is called the *middle* or *soft commissure*.

The free and continuous surface of the optic thalamus and corpus striatum, which projects into the anterior and middle part of each lateral ventricle, is covered by a delicate epithelium, which is continuous with, and of the same nature as, that which lines the whole interior of the ventricle. This epithelium is, probably, ciliated. Beneath it we find a layer of nucleus-like particles, which also extend over the whole internal surface of the ventricles.

The *pineal body*, or *gland* as it has been miscalled, is placed immediately behind the posterior extremity of the third ventricle. It is a cone-shaped body, of a dark gray colour, intimately connected with the deep surface of the velum interpositum, a process of which encloses it and adheres closely to it. It rests in a groove between the nates: its base is turned forwards towards the third ventricle, and its apex is directed downwards and backwards. No part of its base is contained in the third ventricle; but it is connected to the inner surfaces of the thalami by some fibres which pass forwards from each angle of its base. These are called the *peduncles* or *habenæ*, of the pineal gland. A cord of transverse fibres, some of which appear to be continuous with the peduncles, is situated beneath the base of the body; most of these fibres are connected with the posterior extremity of each thalamus, and constitute what is called *the posterior commissure*.

The pineal body consists principally of large nucleated vesicles, and contains some tubular fibres. In a cavity which is formed towards its base, is contained a mass of sabulous matter, which is composed of phosphate and carbonate of lime. To this Sœmmering gave the name *acervulus*. It is found only in subjects after seven years of age, and is in a great degree peculiar to the human subject.

: structure of the pineal body is very imperfectly known; and gh its office has been a theme for some of the wildest specu- in physiological theories, we are still utterly in the dark respect-

the Cerebral Hemispheres.—The hemispheres of the brain are masses, which in man constitute by far the largest portion of cephalon. All that mass of nervous matter which is external iperficial to the optic thalami and corpora striata constitutes the pheres properly so called. A vertical fissure separates the right ft hemispheres, which, although not perfectly symmetrical, very y resemble each other. This fissure contains the great falciform s of the dura mater, which thus forms a septum between the al hemispheres.

en a horizontal section is made through either hemisphere, an urface is exposed (*centrum ovale* of Vieussens), which consists area of white or fibrous matter, bounded by a waving margin y. The latter is about an eighth of an inch in thickness: it is ed on its exterior by pia mater, from which innumerable minute s penetrate it; and within it adheres intimately to the white , the fibres of which extend into it, and mingle with its ele-

xamining the surface of a hemisphere from which the pia mater en stripped, the peculiar folded arrangement of it is manifest. folds, commonly known as the *convolutions* of the brain, re- e the rugæ which are produced in the mucous membrane of the ch when its muscular coat is very much contracted. They are itly destined to pack into a small compass a large surface of ilar matter. A sulcus separates each convolution from the bouring one. The gray matter is found at the bottom of the as well as upon the prominences of the folds, and its union he fibrous matter takes place equally in the one as in the other on. A sulcus, therefore, contains the gray (vesicular) and (fibrous) elements as distinctly as a fold or convolution. It is nt, that if the surface of the gray did not exceed that of the matter, folds or convolutions would not be necessary, but a : expanse of the former would suffice to cover the surface of the The convoluted arrangement increases the vesicular surface immense extent, without occupying much additional space; y the prolongation of the fibres, which correspond to the con- es of the convolutions, some distance beyond those which pene- he gray matter of the sulci, the fibrous matter is adapted to it.

: existence of convolutions on the surface of the hemispheres s evidence of a large relative amount of the dynamic or vesicu- rvous matter in those segments of the brain, and their number omplexity are a measure of the extent to which the vesicular e is increased. Of two brains, equal as regards bulk, and occu- the same space, that which has the more numerous convolutions surface has the greater quantity of vesicular matter, and must garded as physiologically the more potential.

emarkable gradation is observable as regards the number of the

cerebral convolutions from the lowest mammalia up to man. Some of the Rodentia, Cheiroptera, and Insectivora, occupy the lowest place; and monkeys, the elephant, and the whale, rank next to Man, in whom the convolutions reach their highest point of development. In the rat, mole, &c., the surface of the brain is perfectly smooth; and the only tendency to complication which it exhibits, is to be found in the convolution of the gray matter at the fissure of Sylvius. The brains of these animals resemble, in this respect, to a striking degree, those of birds, which are equally destitute of all semblance of a convolution. But in the rabbit, guinea-pig, beaver, &c., the occurrence of certain fissures on the surface of the hemispheres, and the greater depth of the fissure of Sylvius, denote the first steps in the development of convolutions.

A further stage of development is indicated by the existence of certain rounded folds which generally take a direct course parallel to the long axis of the hemispheres. These folds are but few in number, and quite simple, but may be readily distinguished from the rest of the cerebral surface, by the fissures which bound them.

However complicated and numerous the convolutions of the most highly developed brains may be, it cannot be supposed that their arrangement is accidental, or has reference merely to the space within which the brain is enclosed. On the contrary, there seems no doubt that the position, size, and connection of certain primary folds influence mainly the number and variety of those which occupy the intervening spaces. This interesting point has been strongly insisted upon by M. Leuret, who shows, by comparison of the most completely convoluted brain with those in which the folds are few and simple, that the convolutions of the latter, which are, as it were, the original landmarks in this intricate arrangement of the cerebral surface, may be demonstrated in each successive group of brains which form a stage in the ascending series.

Taking the brain of the fox as the standard of comparison, M. Leuret* describes in it six obvious convolutions, prominently marked on the surface of its hemispheres. Four of these are *external*, the uppermost of which occupies also the principal portion of the superior surface; one is *internal*, and situate immediately above and parallel to the corpus callosum: while the sixth is on the inferior surface of the anterior lobe, and rests upon the orbit, whence it is named *supra-orbitar*. Of the four external, the inferior one bounds the fissure of Sylvius above, in front, and behind: and its relation to that fissure enables the observer to distinguish it very readily. The three remaining ones, curved similarly and parallel to the first, and to each other, occupy the remainder of the external, and, in part, the superior surface of the hemisphere.

M. Leuret distinctly traces these convolutions in other groups of animals in which the general organization of the brain has manifestly acquired a considerable increase. Some of them, however, are

* Professor Owen has pursued the same subject extensively, and has given his results in his lectures at the Royal College of Surgeons; but we believe these have not yet been published.

ssured, or exhibit a tortuous appearance; or one or more small ›lds unite neighbouring convolutions at one or more points; or a ssure may be of such depth as to divide a convolution at one ex-'emity into two, either or both of which may form a junction with thers. Thus, from a few primary or fundamental convolutions, a ighly complicated surface of the brain may be formed, by their abdivision, by their tortuosity, and by their junction at various oints, through the intervention of straight or tortuous secondary ›lds.

In some animals, however, the primary convolutions may even be :ss numerous than those above mentioned; and yet the surface of ıe brain may appear more complex, owing to the tortuosity of those rhich do exist, and their subdivision into, or junction with, numerous econdary folds. This is the case in that group of which the sheep ›rms the type. There are but two primary convolutions on the ex-:rnal surface, one of which corresponds to that of the fissure of ylvius in the fox, the other to the one immediately above it; and ıere are the internal convolution and the supra-orbitar one, making ı all only four primary convolutions. Yet the surface of the sheep's rain exhibits a much greater number of folds than that of the fox.

On the other hand, when the brain has acquired an enormous ıcrease of size, as in the elephant and in man, new convolutions eem to be added to the primary ones met with in inferior groups, and ıe secondary folds are greatly increased in number. The additional onvolutions are found chiefly at the superior and anterior part of the emisphere.

In the human brain the following convolutions are constantly pre-ent, and resemble the primitive ones, which have been already eferred to in the brains of the inferior animals. The *internal* one is lways well marked; it lies parallel to the corpus callosum, overlap-ing it slightly on either side. In front it winds round the anterior ıargin of the corpus callosum, and is connected with the convolu-ions of the anterior lobe; posteriorly it divides, appears to be con-inuous with some posterior convolutions, and passes into the middle obe forming the hippocampus major. Numerous small folds pass rom its upper edge to the superior convolutions. The *supra-orbitar* onvolution is well developed, and bears a constant relation to the issure for the olfactory process. The fissure of Sylvius is bounded y a tortuous *external* convolution, which forms numerous connections vith others on the external surface of the brain. In this fissure is ound constantly a group of shallow convolutions, which form what ıas been called by Reil the island, *insula*, from their isolated position, ıaving only deep-seated connections in the vicinity of the corpus triatum. Some *longitudinal* convolutions are found on the superior ınd on the inner surfaces of the hemispheres, uniting with neigh-›ouring ones by means of numerous transverse folds.

According to Leuret, that only can be properly called a convolu-ion which is primary; and these, for the most part, take a direction n the length of the brain. Those which form angles with the pri-ıary convolutions are, in his estimation, mere folds derived from

them, and connecting them to others. When the convolutions are very highly developed, as in man and the elephant, their numerous undulations obscure in a great degree their real direction. Hence many of the primary convolutions in the human brain seem to take a vertical direction.

There are, however, other differences in the convolutions, whether of the brains of the same or of different groups, besides those dependent on form and degree of undulation. These are referable to their depth and their thickness. Animals, even of the same group, or of the same species, exhibit much variety with respect to these points. The wolf has precisely the same convolutions as the fox; but those of the former are deeper, and thicker, as well as more undulating than those of the latter. Much difference is also observable in these respects in the human brain. The convolutions of the female brain are not so deep nor so thick as those of the male. Age, too, causes a marked difference. The convolutions of the child just born, besides being much more simple, and having fewer undulations, are less deep and less thick than those of the adult; and in old age, when the brain has shrunk, the mental faculties being less vigorous and active, the convolutions have become much smaller in every dimension, and water is apt to accumulate in the intergyral spaces.

In man, the convolutions of the right and left hemispheres do not present a perfect symmetry. It is important, however, to notice, that careful examination will invariably display the same essential convolutions on each side, although they present such striking differences in detail that it is at times difficult to recognize the likeness; and it is not a little remarkable, that, in general, the lower the development of a brain, the more exact will be the symmetry of its convolutions. Thus the brains of all the inferior mammalia, even of those which make the nearest approach to man, are exactly symmetrical. The imperfectly developed brain of the child exhibits a similar symmetry; and that of the inferior races of mankind, in whom the neglect of mental culture, and habits approaching those of the brute, are opposed to the growth of the brain, also presents a symmetrical disposition of the convolutions.

A convolution consists of a fold of the gray, or vesicular matter, enclosing a process of the fibrous. The gray matter of neighbouring convolutions is obviously continuous throughout at the bottoms of the sulci, so that it forms one unbroken although undulating sheet over the whole convoluted surface of the brain. That portion of the gray layer which is in contact with the pia mater is purely vesicular, *i. e.*, unmixed with nerve-tubes, with the exception of a few stray ones on the surface; but blood-vessels penetrate it in very great numbers. The more deeply seated portion, however, contains very numerous tubular fibres, which become larger as they approach the white matter. It is very plain, that a large proportion of the constituent fibres of the white matter of the convolutions penetrate the gray matter: these appear to enter it more or less at right angles to that portion of the gray surface with which they are more immediately in relation; and, on the other hand, they converge inwards towards the central parts of

: brain, the corpora striata and optic thalami. A large proportion, :refore, of the white substance of the hemispheres, the *centrum zle*, consists of fibres which establish a communication between the ıy undulating surface and these central gangliform bodies.

We are unable, however, to state that all the fibres of the con- lutions take this inward direction. Some of them, it has been serted, pass from convolution to convolution, uniting those imme- ıtely adjacent, as well as the more remote. Such fibres, did they ist, would pass at right angles to those above described, and parallel the gray surface. They would constitute *intergyral commissures.* ıt the existence of such a series of fibres rests on a foundation too certain to warrant us in speaking confidently respecting it. When brain which has been hardened by long immersion in alcohol is m along the surface of the convolutions, the torn surfaces take on fibrous appearance. But nothing of the kind can be shown in the :sh brain, in which the direction of the fibres which converge to e corpora striata may be as easily demonstrated as upon the hardened e.

The gray matter of the convolutions does not exhibit a uniform lour throughout its entire thickness. Much depends, as regards e depth of colour of the whole layer, upon the quantity of blood its vessels. Compare the gray matter of an anæmic brain with ıt of a healthy one, or, still more, of a congested one, and the ference cannot fail to strike the most superficial observer. The ternal portion has the darkest colour, and the internal in general : lightest. In some convolutions, however, the intermediate layer white, and appears on the section like a white line separating the ıer from the outer layers. This is very obvious in the convolutions ming the exterior of the descending horn of the lateral ventricles. ıis white layer contains fine nucleus-like particles, similar to those ıich form the intermediate layer of the gray matter of the cerebellum; :oincidence of structure between certain convolutions of the brain, d the gray matter of the cerebellum, which, doubtless, is not with- t some physiological significance.

Certain systems of fibres exist in the cerebrum, which seem very idently to unite portions of the same, or of opposite hemispheres. ıe most obvious of these commissures are, the *corpus callosum*, the *terior commissure*, the *posterior commissure*, the *soft commissure*, the *perior longitudinal commissure*, and the *fornix*. All, except the o last, are transverse, and unite parts of the hemispheres of opposite les.

The *corpus callosum* is a thick stratum of transverse fibres, bent at anterior and posterior extremities, situate between the hemispheres, d forming a floor to a portion of the great median fissure which parates them. Its fibrous structure is very apparent to the naked e, the fibres being collected in coarse bundles. On each side it netrates into the hemisphere, under cover of the internal convolu- n already mentioned, which overhangs it in its entire length. It ıs connects the anterior, middle, and part of the posterior lobes of :h hemisphere; at least, its fibres penetrate the hemispheres at these

parts. Foville describes the fibres of this commissure as being derived partly from the posterior columns of the medulla oblongata, from the optic thalami, from the corpora striata, and, lastly, from the fibrous matter of the hemispheres; and although the demonstration of these numerous sources of origin of these fibres is attended with much difficulty, it nevertheless seems highly probable that the numerous fibres, of which so extensive a stratum is formed, would derive their origin from several sources.

The corpus callosum is crossed from before backwards along the median line by two stripes of longitudinal fibres, which, although easily separable, generally lie in close apposition with each other and form a kind of raphé, dividing the upper surface of the corpus callosum into two equal and symmetrical portions. These fibres seem to be commissural in their office.

The *anterior commissure* is a remarkable bundle of transverse fibres; which passes from one hemisphere to the other. It is in its centre a cylinder of fibrous matter, a little thicker than a crowquill, but becoming very much flattened and expanded at its extremities. Its central part is seen at the anterior extremity of the third ventricle, in front of the anterior pillars of the fornix, crossing from side to side, quite free, and unconnected with nervous matter. It plunges on either side into the anterior extremity of the corpus striatum, and, passing through it, its fibres diverge and spread out into the white matter at the floor of the Sylvian fissure, and near the anterior perforated space.

The *posterior commissure* crosses the posterior extremity of the third ventricle, and passes transversely between the optic thalami. It is a slender cylinder of fibrous matter, which lies immediately above the anterior orifice of the aqueduct of Sylvius. On each side it seems to sink into the posterior part of the optic thalamus. The base of the pineal body rests upon it, and is connected with it by fibrous matter, which is continuous with the peduncles.

The *soft commissure* is a soft pale-gray layer consisting of vesicular matter with nerve tubes, which stretches from one optic thalamus to the other, having no other connection, and being free on its upper as well as its under surface. This layer, thus extended horizontally between the thalami, divides the third ventricle into a superior and an inferior portion. As it comprises vesicular matter, it is not a commissure in the same sense as the others, which contain none.

The *superior longitudinal commissure* is enclosed in the internal convolution overhanging the corpus callosum. Posteriorly it passes over the posterior border of the corpus callosum, to the under part of the middle lobe, where it is chiefly connected with the hippocampus major. Anteriorly it winds over the front border of the corpus callosum to join the lower convolutions of the anterior lobe in front of the fissure of Sylvius. Thus it takes a course similar to that of the fornix, though more extensive and superficial.

The *fornix* or *vault* is the most extensive, and in every way the most remarkable of the cerebral commissures. It is placed immediately beneath the corpus callosum, with the posterior half of which

is intimately connected, and from which it is with difficulty sepa-ted. A principal portion of the fornix consists of a horizontal mella of fibrous matter, parallel to the corpus callosum, of a trian-ılar shape, with the apex forwards (*corpus fornicis*). The base is ıclosed by the posterior reflection of the corpus callosum, the termi-ıl transverse fibres of which are seen on its inferior surface, forming ıe appearance which has been designated *lyra*.

The fornix may be divided along the middle line into two equal ıd symmetrical portions, one belonging to each hemisphere. Suf-cient indication of its double form is evinced by the prolongation om its apex of two cylindrical cords, which curve forwards and ownwards, then backwards, with their convexities touching the osterior border of the anterior commissure. These are the *anterior illars* of the fornix. In their descent they diverge slightly from ıch other, leaving an interval between them, through which the ıterior commissure appears. These pillars form the anterior boundary f the *foramen commune anterius*, through which the lateral ventricles ommunicate with the third, and with each other.

Each anterior pillar of the fornix in its descent penetrates the an-rior and inner part of the optic thalamus. Here it is surrounded y vesicular matter, which may be readily scraped away from it. umerous striæ of fibrous matter join the pillar as it passes through ıe vesicular matter; their constituent fibres, doubtless, being derived om the thalamus. Finally, each pillar terminates in a small spheri-ıl body at the base of the brain. These bodies called *corpora amillaria*, are white outside, but when cut into, exhibit a reddish-ray colour, like that of the optic thalami. They contain nerve-tubes ıd vesicular matter in considerable quantity, and therefore resemble anglia in structure. A considerable fasciculus of fibres connects ıch mamillary body with the optic thalamus.

From each angle of the base of the fornix a broad band of fibrous atter passes outwards, and spreads partly into the posterior horn of ıe lateral ventricle, and partly into its descending horn. These ands constitute the *posterior pillars* of the fornix. They connect ıemselves with certain convolutions which project into the posterior ıd inferior cornua of the lateral ventricles; in the latter with the ppocampus minor, and in the former with the hippocampus major.

The fornix consists of longitudinal fibres, unmixed with vesicular atter, save in the optic thalami and corpora mamillaria. The supe-or surface of the body of the fornix is connected to the inferior ırface of the corpus callosum, at its base apparently by the direct lhesion of the fibres of the two planes, but towards its apex by ıe *septum lucidum*, which extends vertically from the middle line of ıe inferior surface of the corpus callosum to that of the superior ırface of the fornix.

From the great extent of the fornix, and the numerous connections hich its pillars form, it is plain that it must serve as a commissure many and distant parts. Each half of it is a longitudinal or antero-osterior commissure for the hemisphere of its own side. It is not ıprobable that some of the convolutions contain antero-posterior

commissures for the superficial part of the hemisphere; such is certainly the case with the longitudinal convolution above the corpus callosum. The fornix, however, connects deep-seated parts, for it passes between the optic thalamus and the deep convolutions of the posterior and middle lobes.

The *septum lucidum* consists of two layers of fibrous matter, which enclose a space or cavity called the *fifth ventricle.* The fibres of this layer radiate upwards and forwards, and connect the anterior pillars of the fornix with the corpus callosum. Each fibrous layer is covered on its outside by a layer of nuclear particles, which again is covered by the membrane of the lateral ventricle.

A band of fibrous matter, which belongs to the same system of commissural fibres as the fornix, is found, on each side, in the groove between the corpus striatum and optic thalamus. This is called *tænia semicircularis.* It may be described as connected with the corpus mamillare, in much the same way as the anterior pillar of the fornix. Traced from this point, it is found to penetrate the optic thalamus, following the general course of the anterior pillar of the fornix, but slightly diverging from it, and to emerge from the thalamus in the anterior part of the groove between it and the corpus striatum, whence it passes backwards, outwards, and downwards into the inferior cornu of the lateral ventricle.

Other structures exist in the brain, which seem likewise to act as commissures to the parts between which they are placed. Thus, between the crura cerebri a layer of fibrous matter, mingled with a few vesicles, is placed, which fills up the angle formed at their divergence; this layer is remarkable for being perforated by numerous foramina, which give passage to the blood-vessels of the locus niger. It is called the *pons Tarini;* it probably connects the gray matter of the crura.

The *innermost fibres of the optic tracts* are evidently commissural. These fibres form an arch, which crosses the tuber cinereum. In the mole, they are the only fibres of the optic tracts existing: those which form the optic nerves are not present. These fibres connect the quadrigeminal tubercles and the geniculate bodies of opposite sides.

The *tuber cinereum* is a remarkable layer of vesicular matter, with which nerve-tubes freely intermingle, which extends from the mamillary bodies forwards to the posterior reflection of the corpus callosum, and has intimate connections with the anterior pillars of the fornix, the optic tracts, the septum lucidum, and, at the floor of the third ventricle, with the optic thalami. An infundibuliform tube passes from it down towards the pituitary gland, which is situate in the sella Turcica.

It is curious how few are the fibres which seem to connect the cerebrum and cerebellum. The only ones to which this office can be assigned are those which form the processus cerebelli ad testes. Hence these structures may more fitly be denominated *cerebro-cerebellar commissures.* They extend between the cerebellum on the one hand, and the optic tubercles and thalami on the other.

)f the manner in which the commissures connect the various parts ween which they are placed, it is difficult to form an exact opinion. the commissural fibres directly continuous with those of the segnts which they unite? or do they intermingle or interlace with m in some intricate way, so that they may come into intimate or quent contact? Or, do they, like other fibres, blend with the gray tter, and thus connect the really dynamic portion of the segments? is latter view seems to be the most probable.

The *pituitary body* or *hypophysis* is a glandiform mass lodged in the la Turcica, and surrounded by the coronary sinus. It is connected th the brain by the infundibular process, the small extremity of ich is attached to its superior concave surface.

This body consists of two lobes, of which the anterior is much the ger; and which also differ in point of colour, the anterior being a yellowish gray, the posterior more similar to the gray matter of brain. The former is considerably denser and firmer than the ter, which does not differ in consistence from the cerebral gray tter. The infundibulum is chiefly connected with the posterior e.

In point of structure this body resembles somewhat the vesicular tter of the brain. We find in it large vesicles with distinct nuclei d nucleoli lodged in a granular matrix, and between them numerous ndles of white fibrous tissue. These are most numerous in the terior lobe. Its use is quite unknown.

Of the Ventricles of the Brain.—By the apposition of the two mispheres of the brain along the median plane, a fissure-like space enclosed beneath the corpus callosum and fornix, limited in front the anterior pillars of the latter, and behind by the posterior commsure; this is the *middle* or *third* ventricle. This fissure is closed eriorly by the pons Tarini, mamillary tubercles, and tuber cinereum; roof is formed by the *velum interpositum*, a process of pia mater, ich separates it from the body of the fornix. It communicates steriorly with the fourth ventricle through the aqueduct of Sylvius *er a tertio ad quartum ventriculum*), and immediately behind the terior pillars of the fornix it freely opens into each lateral ventricle. the same situation the velum interpositum and the choroid plexuses mmunicate with each other. The optic thalami form the lateral undaries of the third ventricle, and its cavity is crossed by the soft mmissure.

The *lateral* ventricles result from the folding of the convoluted rface inwards and downwards. By their extension inwards, and ir junction along the median line by the corpus callosum, the rizontal portion of each ventricle is enclosed; and by the folding rards of the inferior convolutions, posterior to the fissure of Sylvius, inferior horn is formed. The horizontal portion extends into the terior lobe (*anterior* or *frontal horn*), and into the posterior lobe *sterior* or *occipital horn*). The central part of the horizontal porn is separated from the third ventricle by the body of the fornix. this portion of the ventricle are seen the upper surfaces of the corpus iatum and optic thalamus, with the tænia semicircularis between

them, covered by the lamina cornea. The thalamus is partly concealed by the choroid plexus. The descending or inferior horn (*sphenoidal horn*) communicates with the body of the ventricle just behind the corpus striatum, and from that point passes downwards and outwards, and then forwards and inwards. It contains a remarkable convolution, the *hippocampus major*, which projects into it, and is a continuation of that enclosing the superior longitudinal commissure; this is covered by an expansion of fibrous matter continuous with the posterior pillars of the fornix. The posterior horn contains a similar but smaller convolution, called *hippocampus minor*.

The inferior horn of the lateral ventricle contains a considerable portion of the choroid plexus. This enters at its inferior extremity between the hippocampus major and the crus cerebri, and passes upwards into the horizontal portion of the ventricle.

The *fourth* and the *fifth* ventricles have been already described.

All the ventricles are lined by a very delicate membrane, similar in structure to serous membrane. It is covered by a fine epithelium consisting of polygonal scales, and provided with cilia, which were first observed by Purkinje and Valentin. This epithelium is found covering the surface not only of the wall of the ventricle, but also of the pia mater within it, the choroid plexuses, and the deep surface of the velum interpositum. It is by means of the reflection of this membrane upon the intraventricular processes of pia mater that the ventricles are closed at those points where nervous matter does not exist, such as the inferior cornua of the lateral ventricles, and the inferior extremity of the fourth ventricle. There is, therefore, no direct communication of these cavities at these points with the subarachnoid space; and, if fluid pass from one to the other, it must be by filtration through the delicate ventricular membrane.

In a state of health there is little or no fluid in the lateral or other ventricles of the brain. Their inner surfaces are doubtless in contact, but lubricated with a moisture, as all serous surfaces are. When fluid is found in them, it results either from changes which take place after death, or from some morbid process during life. A state of anæmia, or an impoverished condition of the blood, in which its colouring matter and its fibrine are found in small quantity, is very favourable to the effusion of fluid into the ventricles.

It may serve, in some degree, to convey a clearer general idea of the anatomy of the brain, if, in conclusion, we explain the course which the nervous force might, and probably does follow, when developed in any particular segment of this complex organ.

If we suppose the source of power to be the convolutions on either side, the nervous force would be propagated by the fibres of the hemisphere to the vesicular matter of the corpus striatum; from which it would pass along the fibres of the inferior layer of the crus cerebri, through the mesocephale, to the anterior pyramids of the medulla oblongata; along which it would be conveyed to the opposite half of the spinal cord, exciting the nerves which spring from that segment. Supposing this to be the route in which the impulse of volition is propagated to the muscles, it becomes very easy to understand why a

tate of paralysis must ensue, when an apoplectic clot, or other morbid deposit in any part of the course above described, compresses or ruptures the fibres, or when a state of softening destroys their vital powers, or causes a solution of their continuity. If the seat of disease be in the white matter, the channels along which the nervous power travels will be interrupted; if it be in the gray matter, the sources of nervous power are impaired. In all cases the extent of the paralysis will be proportioned to that of the lesion, and for the most obvious reasons.

If the cerebellum be the source of power, the nervous force will travel from either hemisphere along the fibres of the crus, and by those of the restiform body to the spinal cord, and from the continuity of the former with the posterior column of the latter it is probable that this column would be more immediately excited.

So little is known of the precise channels through which impressions created at the periphery are propagated in the central organ, that we can hardly do more than speculate on the subject. We may, however, fairly conclude, that those segments with which nerves admitted to be sensitive are in close connection, must be instrumental in the propagation of the nervous power, when excited by sensitive impressions; and hence we are led to assign to the olivary columns of the medulla oblongata, and their continuations in the mesocephale, with the optic tubercles and the thalami, a considerable share in this office, inasmuch as the auditory, the fifth, and the optic nerves, are intimately connected with them. And admitting, for the present, that the hemispheres are the common centre of sensitive impressions, it is easy to understand how nervous power, excited by the impulse of sound upon the ear, for example, may be propagated along the auditory nerves to the olivary columns in the fourth ventricle, and thence to the optic thalami, in which are found many fibres which are continuous with those of the hemispheres, and capable of propagating the nervous force to the convolutions.

To this it may, however, be objected, that perfect sensation is frequently co-existent with a cerebral lesion, sufficient to produce very complete paralysis of motion, and that an enduring paralysis of sensation is a rare accompaniment of cerebral disease. But such facts do not so much militate against these views, as they serve to denote that the channels of sensation are more numerous than those of motion; and that, if one route be interrupted, another is easily opened. It may be, that the commissures are valuable instruments for this purpose; and it is highly worthy of notice, that no segment of the cerebrum has so many commissures either with the opposite or its own side, as the optic thalamus.

It should be borne in mind that the foregoing remarks are partly conjectural, and that they are introduced rather as a convenient form of illustration, than as implying more than a probability of their general correctness and accordance with the best established views.

Of the Circulation in the Brain.—An organ of such great size, of such high vital endowments, so active, and which exerts so considerable an influence upon all other parts of the body, must necessarily

require a large supply of the vital fluid. Hence we find that the blood-vessels of the brain are numerous and capacious. Four large arteries carry blood to it; namely, the two *internal carotids*, and the two *vertebrals*. Each *carotid* penetrates the cranium at the foramen on the side of the sella Turcica, and almost immediately divides into three branches, the *anterior* and the *middle cerebral* arteries, and the *posterior communicating* artery.

The anterior cerebral arteries supply the inner sides of the anterior lobes of the brain: they ascend through the great longitudinal fissure, and pass along the upper surface of the corpus callosum, giving off branches to the inner convolutions of both hemispheres of the brain. These arteries anastomose with each other just beneath the anterior margin of the corpus callosum by a transverse branch, called the *anterior communicating* artery. The middle cerebral arteries, the largest branches of the carotids, pass outwards in the fissures of Sylvius, and supply the outer convolutions of the anterior lobes, and the principal portion of the middle lobes. At the inner extremity of each fissure of Sylvius numerous small branches of these arteries penetrate, to be distributed to the corpus striatum. The choroid arteries which supply the choroid plexus sometimes arise from these arteries, but also occasionally come from the carotid itself. The posterior communicating artery is an anastomotic vessel, which passes backwards along the inner margin of the middle lobe on the base of the brain, and communicates with the posterior cerebral artery, a branch of the basilar.

The *vertebral* arteries, having passed through the canals in the transverse processes of the cervical vertebræ, enter the cranium through the occipital foramen towards its anterior part. In their ascent they incline towards each other in front of the medulla oblongata, and at the posterior margin of the pons they coalesce to form a single vessel, the *basilar*, which extends the whole length of the pons.

The *vertebral* arteries furnish the *anterior* and *posterior spinal* arteries, and the *inferior cerebellar* arteries. These last vessels arise from the vertebrals very near their coalescence, and pass round the medulla oblongata to reach the inferior surface of the cerebellum, to which they are principally distributed.

The basilar artery sends numerous small vessels to penetrate the pons, and at its anterior extremity divides into four arteries two on each side: these are, the two *superior cerebellar*, and the two *posterior cerebral* arteries.

The superior cerebellar arteries pass backwards round the crus cerebri, parallel to the fourth nerve, and divide into numerous branches on the upper surface of the cerebellum, some of which anastomose with branches of the inferior cerebellar artery over the posterior margin of the cerebellum. Some branches of these arteries are distributed to the velum interpositum.

The posterior cerebral arteries are the largest branches of the basilar. They diverge and pass upwards and backwards round the crus cerebri, and reach the inferior surface of the posterior lobe, anastomosing in the median fissure with ramifications of the anterior

erebral, and on the outside with branches of the middle cerebral rteries. Numerous small vessels pass from this artery at its origin, nd penetrate the interpeduncular space, and one or two are distri- uted to the velum. Shortly after its origin the artery receives the osterior communicating branch from the carotid.

A remarkable freedom of anastomosis exists between the arteries f the brain. This takes place not only between the smaller rami- ications, but likewise between the primary trunks. The former is vident all over the surface of the cerebrum and cerebellum. The atter constitutes the well-known *circle of Willis*. This anastomosis ncloses a space, somewhat of an oval figure, within which are found he optic nerves, the tuber cinereum, the infundibulum, the corpora namillaria, and the interpeduncular space. The anterior communicat- ng artery, between the anterior cerebral arteries, completes the circle n front. The lateral portion of the circle is formed by the posterior ommunicating artery, and it is completed behind by the bifurcation f the basilar into the two posterior cerebral arteries. Thus, a stop- age in either carotid, or in either vertebral, would speedily be emedied. The coalescence of the vertebrals to form the basilar, ffords considerable security to the brain against an impediment in ne vertebral; and, should the basilar be the seat of obstacle, the nastomoses of the inferior cerebellar arteries with the superior ones vould insure a sufficient supply of blood to that organ. If either or oth carotids be stopped up, the posterior communicating arteries vill supply a considerable quantity of blood to the intracranial por- ions of them; or, if one carotid be interrupted, the anterior commu- nicating branch will be called into requisition to supply blood from he opposite side.

Obstruction to the circulation in both carotids and both vertebrals s productive of a complete cessation of cerebral action, and death mmediately ensues, unless the circulation can be quickly restored. This was proved clearly by Sir A. Cooper's experiments on rabbits. The circulation may, however, be interrupted in both carotids, or in oth vertebrals, without permanent bad effect; or in one carotid or ne vertebral, provided the condition of the remaining vessels be uch as not to impede the circulation in them. In cases where the eighbouring anastomotic branches are not sufficient to restore the irculation to a part from which it has been cut off by the obliteration f its proper vessel, the cerebral substance of that region is apt to xperience a peculiar form of softening or wasting, which is distin- uished by the absence of any discoloration by the effusion of blood, nd of any new matter.

The four great channels of sanguineous supply to the brain are ontinued up straight from the aorta itself, or from an early stage of he subclavian. The contained columns are propelled very directly owards the base of the brain, through wide canals. Were such olumns to strike directly upon the base of the brain, there can be o doubt it would suffer materially. Considerable protection, how- ver, is afforded to the brain; first, by the blood ascending against ravity, during at least a great portion of life; secondly, by a tortuous

arrangement of both carotids and vertebrals before they enter the cranial cavity, the carotid being curved like the letter S in and above the carotid canal, and the vertebral being slightly bent between the atlas and axis, then taking a horizontal sweep above the atlas, and after it has pierced the occipito-atlantal ligament, inclining obliquely upwards and inwards; thirdly, by the breaking up of the carotids into their branches, by the inclined position of the vertebrals, and by their junction into a single vessel, which takes a course obliquely upwards, and afterwards subdivides into smaller branches. Such arrangements most effectually break the force of the two columns, and, as it were, scatter it in different directions.

A further conservative provision is found in the manner in which the blood-vessels penetrate the brain. The larger arterial branches lie in sulci between convolutions, or at the base of the organ; small branches come off from them, and ramify on the pia mater, breaking up into extremely fine terminal arteries, which penetrate the brain; these latter vessels spring directly from the larger branches, and enter the cerebral substance. As a general rule, no vessel penetrates the cortical layer of the brain, which, in point of size, is more than two removes from the capillaries; and, whenever any vessel of greater size does pierce the cerebral substance, it is at a situation where fibrous matter is external, and the part perforated by foramina for the transmission of the vessels. Such places are the locus perforatus, the interpeduncular space, &c. The accompanying figure shows the manner in which the terminal arterial twigs dip vertically into the cerebral substance, and break up into a solid plexus of capillaries in the stratum of vesicular matter. The capillary plexus of the fibrous or white matter has similar characters, only its meshes are much wider (fig. 72). The capillaries of the cerebral substance are easily seen to possess an independent diaphanous wall, with cell-nuclei disposed at intervals. The smaller arteries and veins can be admirably studied in the pia mater of the brain.

Fig. 72.

[illegible]

The venous blood is collected into small veins which are formed in the pia mater at various parts of the surface, and in the interior of the brain. The superficial veins open by short trunks into veins of the dura mater, or into the neighbouring sinuses: the superior longitudinal, the lateral, and the straight sinuses receiving the greatest number. Those from the interior form two trunks, venæ magnæ Galeni, which pass out from the ventricles between the layers of the velum interpositum. The cerebral veins are devoid of valves.

We remark here, that the venous blood of the brain is returned

ntre of the circulation through the same channels as that of ıra mater, of the cranial bones, and of the eyeball: the deep .r veins are the outlets by which the venous blood of the m is discharged. An obstacle, therefore, in both or either of trunks must affect the entire venous system of the brain, or at hat of the corresponding hemisphere. A ligature tied tightly the neck impedes the circulation, and may cause congestion brain. The bodies of criminals who have died by hanging .t great venous congestion, both of the walls and the contents of anium, in consequence of the strong compression to which the have been submitted.

: have seen, that, when the blood of one carotid artery is cut off, rts usually supplied by it are apt to become exsangueous and ed; and this is more especially the case if the vertebral be also ted, or the circulation in it impeded. And it has been remarked, hese effects will follow the application of a ligature to either on carotid artery.

withstanding these facts, a doctrine has received very general , and the support of men of high reputation, which affirms that solute quantity of blood in the brain cannot vary, because that is incompressible, and is enclosed in a spheroidal case of bone, ich it is completely exempted from the pressure of the atmo- :.

: cranium, however, although spheroidal, is not a perfectly solid but is perforated by very numerous foramina, both external and al, by which large venous canals in the diploë of the bones unicate with the circulation of the integuments of the head as s with that of the brain; so that the one cannot be materially d without the other suffering likewise. And as the circulation integuments is not removed from atmospheric pressure, neither at which is so closely connected and continuous with it, be said ree from the same influence. Still it must be admitted, that the osition of the central vessels, and the complicated series of els through which they communicate with the superficial ones, t them in some degree from the pressure of the air, and render ess amenable to its influence than the vascular system of the e.

t were essential to the integrity of the brain that the fluid in its vessels should be protected from atmospheric pressure asthe ates of this doctrine would have us to believe), a breach in the l wall would necessarily lead to the most injurious consequences; ow frequently has the surgeon removed a large piece of the cra- by the trephine without any untoward result! We have watched veral weeks a case in which nearly the whole of the upper part cranium had been removed by a process of necrosis, exposing a arge surface to the immediate pressure of the atmosphere; yet in ase no disturbance of the cerebral circulation existed. In the and open fontanelles of infants we have a state analogous to that art or disease produces in the adult: yet the vast majority of s are free from cerebral disease for the whole period during

which their crania remain incomplete; and in infinitely the greatest number of cases in which children suffer under cerebral disease, the primary source of irritation is in some distant organ, and not in the brain itself.

Neither can it be said that the brain is incompressible. That only is incompressible, the particles of which will not admit of being more closely packed together under the influence of pressure. That the brain is not a substance of this kind, is proved by the fact that, while it is always undergoing a certain degree of pressure, as essential to the integrity of its functions, a slight increase of pressure is sufficient to produce such an amount of physical change in it as at once to interfere with its healthy action. Too much blood distributed among its elements, and too much serum effused upon its surface, are equally capable of producing such an effect.

Magendie's experiments, alluded to at p. 231–2, show that the brain and spinal cord are surrounded by fluid, the pressure of which, probably, antagonises that which must be exerted through the blood-vessels. The removal of this fluid disturbs the functions of these centres apparently by allowing the vessels to become too full. The pressure exerted by the former we shall call the fluid-pressure from without the brain; that by the blood, the pressure from within. As long as these two are balanced, the brain enjoys a healthy state of function, supposing its texture to be normal. If either prevail, more or less of disturbance will ensue. Their relative quantities, if not in just proportion, will bear an inverse ratio to each other. If there be much blood, the surrounding fluid will be totally, or in a great measure, deficient; if the brain be anæmic, the quantity of surrounding fluid will be large.

The existence of these two antagonizing forces may be taken as a proof that either of them may prevail; and therefore, from the existence of the cerebro-spinal fluid we may infer that the actual quantity of blood circulating in the brain is liable to variation.

This fluid is a valuable regulator of vascular fullness within the cranium, and a protector of the brain against too much pressure from within. So long as it exists in normal quantity, it resists the entrance of more than a certain proportion of blood into the vessels. Under the influence of an unusual force of the heart, an undue quantity of blood may be forced into the brain; the effects of which will be, first, the displacement of a part, or of the whole surrounding fluid, and, secondly, the compression of the brain.

On the other hand, the brain may receive too little blood. In such a case, if the surrounding fluid do not increase too rapidly, the requisite degree of pressure will be maintained, and the healthy action of the brain preserved. But, if the brain be deprived of its due proportion of blood by some sudden depression of the heart's power, there is no time nor source for the pouring out of new fluid, and a state of syncope, or of delirium, will ensue. Such seems to be the explanation of those cases of delirium which ensue upon hemorrhages, large bleedings, or the sudden supervention of inflammation of the pericardium or endocardium. In many of these cases, however, it is important to notice, that the blood is more or less damaged in quality,

cient in some of its staminal principles, or charged with some mor- matter; and this vitiated state of the vital fluid has, no doubt, a siderable share in the production of the morbid phenomena.

he following inferences, which are of practical application, will a suitable conclusion to these remarks on the circulation within cranium.

. That the brain, although not so amenable to the influence of ospheric pressure as more superficial parts, is sufficiently so to it of variations in the quantity of its circulating fluid.

. That, consequently, general or local bleeding will exert the e kind of influence upon the circulation in the brain, as in other ns, so far as relates to diminishing the quantity of blood in it.

. But that the brain is liable to suffer from the loss of blood in a rent way from other viscera, inasmuch as copious bleeding may sion serious disturbance in the functions of the brain by lessen- the force of the heart's action, and thereby depriving the brain hat amount of pressure on its vascular surface which seems essen- to its healthy action.

. That the depression of the heart's force from any other cause, apable of producing similar cerebral disturbance for the same ons.

e following works may be consulted upon the subjects treated of in this chapter: uveilhier's Anat. Descr. t. iv.—Meckel, Anat. Gén. Descr. et Pathol. t. ii.—Reil's ys, translated in Mayo's Anat. and Phys. Commentaries.—The article Nervous res in the Cyclopædia of Anatomy.—Mayo's Plates of the Brain.—Stilling und ach, Untersuchungen über die Textur des Rückenmarks. Leipz. 1842.—Still- über die Textur und Function der Medulla oblongata. Erlang. 1843.—Foville, . du Syst. Nerveux. Par. 1844.—Leuret, Anat. Comparée du Syst. Nerveux. 1839.

e subject of the circulation in the brain has been treated with great acuteness earning by Dr. George Burrows, in the Lumleian Lectures for 1843, Lond. Med. tte, vol. xxxii.

CHAPTER XI.

HE SPINAL NERVES.—OF THE ENCEPHALIC NERVES.—METHOD OF ETERMINING THE FUNCTIONS OF NERVES.—OF THE FUNCTIONS OF HE SPINAL CORD AND ENCEPHALON.

EFORE we can satisfactorily investigate the functions of the cere- spinal centre, or of its various segments, it will be necessary to some account of the nerves which are connected with them.

hese nerves are described in two classes, the *spinal* and the *ence- ic*. The former class consists of all those which arise from the al cord, and emerge from the spinal canal through orifices in its . The latter consists of those which are connected with the phalon.

f the spinal nerves.—There is a pair of spinal nerves for each

pair of intervertebral foramina on the same level, and for those between the atlas and occiput. We can thus enumerate in all thirty-one pair of nerves having their origin from the spinal cord, exclusive of the spinal accessory nerve, which is connected with the upper part of the cervical region.

The spinal nerves have the following very constant characters. Each has its origin by *two roots*, of which the anterior is distinctly inferior in size to the posterior (fig. 61, *p*, *a*, p. 205). The ligamentum denticulatum is placed between these roots. Each root passes out by a distinct opening in the dura mater. Immediately after its emergence a ganglion is formed on the posterior root, and the anterior root lies imbedded in the anterior surface of the ganglion, and inclosed in the same sheath, but without mingling its fibres with those of the ganglion. Beyond it, the nervous fibres of both roots intermingle, and a compound spinal nerve results. The trunk thus formed passes immediately through the intervertebral canal, and divided into an anterior and posterior branch (fig. 61, *a'*, *p'*). The former is in general considerably the larger. The latter passes backwards, and sinks in among the muscles of the posterior regions of the trunk. The anterior branches in the cervical, lumbar, and sacral regions form large and intricate plexuses, (cervical, axillary, lumbar, and sacral,) from which nerves are furnished to the extremities and the anterior part of the trunk.

The first spinal nerve, called by Winslow the *suboccipital*, offers an exception to this arrangement. Generally it arises by two roots, of which, however, the anterior is the larger. Sometimes it has only one root, corresponding to the anterior.

The spinal nerves are arranged naturally in classes, according to the regions of the spine in which they take their rise. We number eight in the cervical region, the suboccipital included; twelve in the dorsal region; five in the lumbar, and six in the sacral regions. All the nerves after the second pass obliquely outwards and downwards, from their emergence from the spinal cord to their exit from the vertebral canal; and this obliquity gradually increases from the higher to the lower nerves, so that the inferior ones are nearly perpendicular, and, as their intraspinal course is of some length, they are collected into a leash, which constitutes the *cauda equina*.

All the spinal nerves arise from the cord by separate fasciculi of filaments, which, as they approach the dura mater, converge to each other, and are united together to constitute the anterior or the posterior roots. The posterior roots arise at a pretty uniform distance from the posterior median fissure in all regions of the cord, indicating but a very trifling change in the thickness of the posterior columns throughout their entire course. Not so the anterior ones: they are farthest from the anterior median fissure in the neck, but very near it in the dorsal region; this difference being due to the variation in the thickness of the antero-lateral columns in the different regions. The ganglia on the posterior roots are always proportionate in size to the roots themselves.

In tracing the mode of connection of the roots of the spinal nerves

ith the cord, great care is required, from the sudden change of consistence which their fascicles experience on penetrating the substance f the cord. They lose the sheath of pia mater which gave firmness that part which is external to the cord, and soon break up into their omponent fibrillæ. For this reason, the specimen employed for the issection should be quite recent, and slightly hardened by previous nmersion in spirit.

The anterior roots penetrate the lateral part of the antero-lateral olumns. Their fibres soon radiate, some passing upwards and inrards, others horizontally inwards towards the centre of the cord, ningling, no doubt, with the elements of the vesicular matter comosing the anterior horn. It is a matter of uncertainty whether the bres which take an upward course pass into the gray matter, or simply aerge into the longitudinal fibres of the cord and pass upwards to the rain. Mr. Grainger's researches lead him to suppose that each root onsists of a double set of fibres,—one which penetrates, and has its rigin from, the gray matter, and the other which is continuous with he longitudinal fibres. This view is considered to derive probaility from the hypothesis which ascribes the voluntary and involunary actions of the cord to two distinct series of fibres, of which one s under cerebral influence, and the other merely excito-motory, and t might be acknowledged to do so, if the necessity of distinct fibres or the two kinds of action were first proved. It is possible, howver, that *all* the fibres penetrate and arise from the gray matter. But we have seen nothing to justify Stilling and Wallach's assertion, hat the anterior and posterior roots coalesce in the gray matter, formng loops, the convexities of which are directed to the centre of the ord; and we have already stated our reasons (p. 236) for doubting he fibrous nature of the lines which these writers represent as radiatng between the gray matter and the surface of the cord.

The posterior roots adhere to the posterior part of the anteroateral column, and are doubtless closely connected with the posterior orns of gray matter. In separating the columns of the cord along the ine of sequence of the fascicles of the posterior roots, we have always ound these roots to remain with the antero-lateral columns, and to ave little or no connection with the posterior ones. We would herefore refer the origin of these nerves to the posterior horns of gray natter, and to the posterior part of the antero-lateral columns.

Of the encephalic nerves.—The arrangement of these nerves, oriinally proposed by Willis, although open to many objections, has evertheless been so long adopted in this country and on the Coninent, and is so constantly used by scientific as well as practical riters, that to abandon it would be productive of great inconvenince, and would be of no advantage, unless some other arrangement f unexceptionable kind could be substituted for it. In the absence of ny such new mode of arrangement, we propose to adhere to that of Willis; at the same time remarking, that much of the imperfection of t is obviated by naming each pair of nerves from some prominent eature either of its function or its anatomical connections.

Twelve pairs of nerves are found connected with the base of the

encephalon. Five pairs have been so classed by Willis as to form two in his arrangement; three pairs being allotted to his eighth pair of nerves, and two to his seventh. Willis' arrangement, therefore, comprises the following nine pairs of nerves, which he enumerates in passing from the anterior to the posterior part of the base; the first pair, or *olfactory* nerves; the second pair, or *optic;* the third pair, *motores oculorum;* the fourth pair, *pathetici;* the fifth pair; the sixth pair, *abducentes oculum;* the seventh pair, including the *portio mollis* or *auditory* nerve, and the *portio dura* or *facial* nerve; the eighth pair, including the *glosso-pharyngeal*, the *pneumo-gastric*, and the *spinal accessory;* the ninth pair, or *hypoglossal.* Willis included among his encephalic nerves the first cervical nerve or *sub-occipital*, which he therefore numbered as the tenth pair.

As the cranium may be shown to be composed of the elements of three vertebræ, it has been attempted to prove that among these nerves some may be classed with the vertebral or spinal nerves. The fifth is obviously of this kind, from its anatomical characters, namely, two roots; one small, ganglionless, the other large, ganglionic; and with the former, the analogue of the anterior spinal root, the third, fourth, and sixth nerves may be conjoined from their similarity in structure and distribution. Thus one *cranio-vertebral* nerve is formed, the anterior or motor root of which consists of the smaller portion of the fifth, the third, fourth, and sixth nerves, and the posterior or sensitive root of the larger portion of the fifth. A second cranio-vertebral nerve consists of the eighth pair, to which might be added the facial, contributing to its motor portion. A third is formed by the hypoglossal,* but the analogy, in the latter case, is certainly far from obvious.

How to determine the function of a nerve?—It has been stated in a former chapter that nerves evince special properties, depending on the connections which they form at the periphery, or at the centre; that they may be divided into motor, sensitive, and, according to one view, excito-motor, according to the manner in which they respond to particular stimuli; and that fibres possessing each of these endowments may be bound together in a common sheath as one nerve. To determine with precision the office which each nerve performs is a problem of great importance, not only from its bearing upon the physiology of the nervous centres, but from its great practical value in the diagnosis and treatment of disease.—(Introd., p. 47.)

The following are the means on which we should rely, in order to determine the function of a nerve.

First, *its anatomy in man.*—The origin by a double root denotes a double function. Its peripheral distribution, however, gives more valuable assistance. If distributed to muscles only, it clearly must be motor; if to sentient surfaces only, sensitive and perhaps excitor; if to both, motor, and sentient, or excito-motor.

Secondly, *its anatomy in animals.*—The comparison of the origin and distribution in the lower animals with those in man often throws light on the function, by confirming the result of anatomical investi-

* Müller's Physiology by Baly, vol. i. p. 841.

ation in the human subject, or by displaying either a peculiar development of the nerve, in reference to some special function proper to particular animals; or, on the other hand, the non-development of a nerve, or of a part of one, where some function may be deficient. The enormous development of a branch of the fifth nerve in animals with proboscides, or highly tactile snouts,—of a branch of the facial, where such an organ is very movable,—the small size of the latter nerve where the muscles of the face are few, are instances quite in point.

Thirdly, *experiment* on animals just dead, or on those living.—The irritation of a motor nerve in an animal recently dead causes contraction of the muscles to which it is distributed. The section of one in a living animal paralyses its muscles; but irritation of the portion below the section causes contraction of those muscles which that segment of the nerve supplies. The simplest way of applying a stimulus for experimental purposes is by passing a galvanic current from a small battery. If the current be directed through a nerve so that it shall pass along the smallest portion of it, by placing one pole on one side of it, and the other on the opposite, but a little lower down or higher up, we may gain a strong indication of the motor power of the nerve, if contractions are thereby excited. This indication becomes certain if the same effect be produced by galvanizing the nerve in this way, after it has been separated from all connection with the spinal cord or brain. Such an experiment on a sensitive nerve would produce no motor effect. Matteucci has shown that to produce the motor effect in a motor nerve, the current must pass *along* some portion of the nerve-fibre, however small; and that a current directed precisely at right angles to the fibres will not excite nervous power.*

MM. Longet and Matteucci affirm that a motor nerve may be distinguished from a compound one by the different effect of opening or closing an electric current on each under certain circumstances. It had already been ascertained by Lehot, Bellingeri, Nobili, and Marianini, that compound nerves, the sciatic, for instance, are at first excited equally on closing and on opening the electric circuit, whether the current be direct (*i. e.* from the brain or cord to the nerves), or inverse (from the nerves to the brain or cord); but after a time they are excitable, as shown by the contraction of the muscles below the point of the nerve stimulated, only on *closing the direct current* or *opening the inverse.* With a purely motor nerve, however, such as the anterior root of a spinal nerve, a different result is obtained; inasmuch as the contractions of the muscles can only be excited *on opening the direct current* or *closing the inverse.*†

Sometimes we find that, if the trunk of a nerve be divided at some distance from its origin, irritation of the central segment will excite contractions, whilst that of the peripheral one will fail to do so. Such a nerve has been called an *excitor;* for it causes muscular movement,

* See an account of Matteucci's observations on the different effects of electricity on nerves, in the appendix to this chapter.

† Matteucci et Longet, sur la relation qui existe entre le sens du courant électrique et les contractions musculaires dues à ce courant. Paris, 1844.

not by its direct influence upon muscles, but by exciting the centre, which in its turn stimulates *motor* nerves arising from it. We judge a nerve to be sensitive, if, when irritated in man or the lower animals during life, a peculiar sensation or pain be excited; or if section of it destroys the sensibility of the parts to which it is distributed.

Fourthly. *Clinical observation* furnishes most valuable opportunities of testing the true function of nerves. We observe a particular form of paralysis, and we inquire what nerve is diseased; we find pain felt in particular regions, and we ascertain that this is in consequence of a morbid state of particular nerves; certain functions are impaired or suspended, if certain nerves be affected with disease. A woman, lately in King's College Hospital, had a singular train of symptoms, which were at first referred to hysteria. However, in a little time they became so confirmed, that no doubt could be entertained of organic lesion. There were ptosis of the upper lids,—paralysis of the muscles of the eyeball supplied by the third nerve,—paralysis of the pharynx, so that the power of deglutition was destroyed,—paralysis of the trapezii muscles, and of those on the back of the neck,—great feebleness of voice. She died like one asphyxiated. After death, the following nerves were found involved in a thickened neurilemma, with altered nerve-tubes,—the third pair, the fourth pair on the left side, the glossopharyngeal, the vagus, the spinal accessory; each of which contributed more or less to supply with nerves the parts paralyzed.

Functions of the roots of spinal nerves.—The application of anatomical investigation, and of experiment, to determine the functions of the anterior and posterior roots of spinal nerves respectively, was the first important step towards a right understanding in the physiology of the nervous system. This was undoubtedly taken by Sir C. Bell; and, although there were other labourers in the same field not unworthy claimants of some share in the merit of this important investigation, it cannot be denied that the endowments of the roots were discovered by Bell.

The original experiments of Bell, in which he was assisted by the late Mr. John Shaw, consisted in laying open the spinal canal in rabbits, and irritating or dividing the roots of the spinal nerves. Bell distinctly affirmed that irritation of the anterior roots caused muscular movement, and that the posterior roots might be irritated without giving rise to any muscular action. Destruction of the posterior roots did not impair the voluntary power over the muscles. Hence it was inferred that the anterior roots were motor, and the posterior roots not motor; but, from the violence of the operation, and the pain produced in performing it, the experiments having been tried on rabbits, it was impossible to determine what degree of sensibility remained in parts supplied from the divided roots.

Numerous subsequent experimenters arrived at similar results to those of Bell; but no one obtained such satisfactory conclusions as Müller, who adopted the expedient of experimenting on frogs instead of mammalia, with which latter the experiments involved the necessity of a tedious and painful operation, and much bloodshed. In

ogs, on the contrary, from the great width of the lower part of the spinal canal, the roots of the nerves can be exposed with facility, and their excitability lasts sufficiently long to yield every result. These experiments we have repeated frequently, with results precisely similar to those which Müller obtained.

In the experiments on frogs, irritation, mechanical or galvanic, of the anterior root always provokes muscular contraction. No such effect follows irritation of the posterior root. Section of the anterior root causes paralysis of motion; that of the posterior, paralysis of sensation. This latter effect is evinced by the utter insensibility to pain shown on pinching a toe, whilst in the limb in which the posterior root is entire such an irritation is evidently acutely felt. If the anterior roots of the nerves to the lower extremity be cut on one side, and the posterior roots on the other, voluntary power without sensation will remain in the latter, and sensation without voluntary power in the former.

Valentin, Seubert, Panizza, and Longet have performed similar experiments upon mammiferous animals with precisely the same effects.

The conclusion to be derived from these experiments is as follows: *that the anterior root of each spinal nerve is motor, and the posterior sensitive.*

Comparative anatomy confirms this conclusion, by showing that a similar arrangement of the spinal roots prevails among all classes of vertebrate animals, and that if, in any particular class of animals, either the motor or sensitive power predominate, there is in correspondence with it a marked development of the anterior or posterior roots; and the frequent occurrence of paralysis of sensation and motion, as a consequence of disease within the spinal canal, also tends to the same inference.

Magendie affirms that the anterior root is slightly sensitive, owing, as Kronenberg has shown, to an anastomotic filament which it derives from the posterior root.

Functions of the spinal cord.—Since nerves of sensation and motion have their origin from the cord, it cannot be doubted that this organ is the medium for the reception and propagation, first, of sensitive impressions made upon those surfaces on which its nerves are distributed, and secondly, of those impulses which are the ordinary excitants of muscular movements.

Experiment and clinical observation, however, show that sensation and *voluntary* motion are not connected with, or dependent on, the spinal cord *alone*. If the connections of this organ with the encephalon be perfect, and uninterrupted by any solution of continuity, morbid deposit in it, or morbid growth causing compression, then the essential condition for the full play of the nervous force, whether for sensation or voluntary motion, is fulfilled. But if the cord be severed just below the plane of the occipital foramen, as when an animal is pithed, all voluntary power over the parts supplied by spinal nerves ceases, and all sensation in those parts disappears at the same time.

Here the cord itself is uninjured; but its continuity with the encephalon is destroyed.

In cases of injury to the vertebral column, causing fracture and displacement of the vertebræ, and destruction of the cord, the parts supplied from that portion of the cord which is below the seat of injury are paralyzed as regards voluntary motion and sensation. The higher the seat of injury, the more extensive will be the paralysis. A man who has received extensive injury of the spinal cord in the neck, is like a living head and a dead trunk,—dead to its own sensations, and to all voluntary control over its movements.

Similar remarks may be made respecting those cases in which disease, or compression of the cord by some intra-spinal growth, has interrupted its continuity in some region. The extent of the paralyzed parts always affords a correct indication of the seat of the solution of continuity.

If the spinal cord be divided partially in the transverse direction, there will be paralysis of parts *on the same side* with the injury inflicted. A longitudinal section of the cord along the median line does not cause any paralysis; a temporary disturbance of its functions, however, ensues, which soon subsides.

So long, then, as the spinal cord and encephalon are continuous, and in their normal state, the former organ must be regarded as specially adapted to receive and propagate sensitive impressions from the trunk and extremities, or to convey the stimulus of volition to their muscular nerves.

There is nothing, however, in these facts to denote that the spinal cord does not share, in some degree in the function of sensation and voluntary motion. All that we are justified in inferring from them is, that the union of the encephalon with the spinal cord is necessary for voluntary motion and for sensation.

Indeed, the recent discovery of the *amphioxus lanceolatus*, a small fish found in the Archipelago, makes it probable that voluntary motion and sensation may exist where there is a well-developed spinal cord, the anterior extremity of which tapers to a fine point, and is far from exhibiting the ordinary characteristics even of a brain so inferior in organization as that of fishes.*

In most instances where the spinal cord has been divided, whether by design or accident, it has been found that, although the will cannot move the paralyzed parts, movements do occur in them of which the individual is unconscious, and which he is wholly unable to prevent. These take place sometimes as if spontaneously, at other times as the effect of the application of a stimulus to some surface supplied by spinal nerves. The apparently spontaneous movements frequently resemble voluntary actions so closely, that it is almost impossible to distinguish them.

These phenomena occur in all classes of animals, warm-blooded as well as cold-blooded. In the latter, however, they are much more marked; the nervous force endures much longer in these animals than

* Goodsir, in Ed. Philos. Transactions, and Cyclop. of Anat., vol. iii., p. 615.

the higher classes of mammalia and birds, just as we have already en that the muscular power does, although we have no reason to ppose that either force is more energetic, because it is more enduring. n this account cold-blooded animals must be selected for exhibiting e phenomena; and accordingly hosts of frogs, salamanders, snakes, rtles, and fishes have fallen a prey to the experimental researches the numerous physiologists who have devoted themselves to these vestigations.

The following experiments serve to illustrate these actions:

If a frog be pithed by dividing the spinal cord between the occi-tal hole and the first vertebræ, an universal convulsion takes place hile the knife is passing through the nervous centre. This, how-rer, quickly subsides; and, if the animal be placed on a table, he ill assume his ordinary position of rest. In some exceptional cases, owever, frequent combined movements of the lower extremities will ke place for a longer or shorter time after the operation. When all ich disturbance has ceased, the animal remains perfectly quiet, and if in repose, nor does there appear to be the slightest expression pain or suffering. He is quite unable to move by any voluntary fort. However one may try to frighten him, he remains in the same ace and posture. If now a toe be pinched, instantly the limb is awn up, or he seems to push away the irritating agent, and then aws up the leg again into its old position. Sometimes a stimulus this kind causes both limbs to be violently moved backwards. A milar movement follows stimulation of the anus. If the skin be nched at any part, some neighbouring muscle or muscles will be rown into action. Irritation of the anterior extremities will occa-on movements in them; but it is worthy of note, that these move-ents are seldom so energetic as those of the lower extremities.

It is not out of place to state here, that phenomena of this kind e not confined to the trunk and extremities which are supplied by inal nerves only. The head and face with which the encephalon mains in connection exhibit similar actions. The slightest touch to e margin of either eyelid, or to the surface of the conjunctiva, causes stantaneous winking; the attempt to depress the lower jaw, for the rpose of opening the mouth, is resisted; and the act of deglutition provoked by applying a mechanical stimulus to the back of the roat.

The stimuli which excite these movements are those ordinary ones hich are capable of calling nervous power into play, such as mecha-cal irritation, heat, cold, galvanism, chemical irritants.

There can be no grounds for supposing that the will has anything do with these movements. An animal pithed, which is to all in-nts and purposes in the same condition as one decapitated, shows sign of voluntary action, excepting perhaps for a short time after e operation, whilst the irritation caused by the division of the cord mains. He maintains one and the same position, without evincing y sign of sense or motion, unless a stimulus be applied to some rt of the surface; and, after the movement which such a stimulus cited has ceased, he resumes the same state of inactivity.

Comparing this state of a pithed or decapitated animal with the phenomena which we know to take place in the human subject in effect of particular forms of accident or disease, it is impossible to regard these actions in any other light than as involuntary ones. To refer once more to such a case as that cited in a former paragraph, when, from the destruction of the cervical part of the cord, the trunk appears as if dead, while the head lives, we find in many instances, if the stunning effect have not been too great, that similar motions to those described in the frog may be produced by the application of mechanical or other stimuli to the surface. Tickling the soles of the feet causes movements of the lower extremities: the introduction of a catheter into the urethra, which is not felt by the patient, excites the penis to erection. Over these acts not only have the patients no control, but they are absolutely unconscious of their occurrence, as well as of the application of the stimuli by which they were provoked. It is plain, then, that these movements take place without the concurrence or even the cognizance of the *mind*, whether as the recipient of stimuli, or as the source of voluntary impulses.

In hemiplegia, the result of diseased brain, when the paralysis is complete, the influence of the will over the paralyzed side is altogether cut off. In such cases, movements may be excited in the palsied leg—very rarely in the arm—by stimuli applied to the sole of the foot, or elsewhere; and we often astonish the patient himself, who expresses his utter inability, by any effort of his will, to move his leg, by exciting active movement of it on touching the sole of the foot very lightly with a feather. It is proper to add, that there is much variety as regards the extent to which these actions take place in hemiplegic cases, owing to causes which are not yet fully understood. Still, they do occur in a large proportion of instances, and in the most marked way. In most of the cases of hemiplegia the surface retains its sensibility; but in most of those of paraplegia sensibility is much diminished or completely destroyed.

In the anencephalic fœtus, in which all the encephalon but part of the medulla oblongata is wanting by congenital defect, actions take place in obedience to stimuli propagated to the cord from some surface, or applied directly to it; but no movements are seen which can be supposed to originate in an effort of the will, nor is there any proof of the existence of sensibility.

Other facts may be adduced in evidence of the involuntary nature of these movements.

It is remarkable that actions of this kind will continue to be manifested after decapitation, not only in the trunk, but also in segments of it with which a portion of the spinal cord remains in connection. If the body of a snake or an eel be divided into several segments, each one will exhibit movements for some time, upon the application of a stimulus. The same thing may be observed in frogs, salamanders, turtles, and other cold-blooded creatures. In birds and mammalia, however, they are less conspicuous, because in them the nervous power is so soon extinct.

These facts suggest an obvious comparison between the spinal cord

:brate animals and the abdominal ganglionic chain of articulate brata. In the latter, each segment of the body has its proper nic centres, and is, therefore, to a certain extent, independent rest. Every schoolboy has witnessed the writhings of an orm, which his mischievous propensity has prompted him to into several pieces. Movements will continue in each piece as the irritation produced by the subdivision remains; and, at has ceased, movements may be excited in any segment by ting its surface. These movements seem precisely analogous e which may be excited in the subdivisions of the trunk of a ate animal. The spinal cord, then, may be viewed as one ious centre, made up of a number of segments fused together extremities. In the árticulate ganglionic chain the centres of ments remain distinct, although connected by fibres which pass ie to the other.

n the spinal cord is divided about its middle, a remarkable ice may be noticed in the effects of irritation on the anterior posterior segment, as shown in some of Flourens' experiments. the anterior segment (that which still retains its connection e brain) is irritated, not only are movements of the anterior ities produced, but the animal evinces unequivocal signs of but, when the posterior segment is irritated, the animal seems y insensible to pain, but unconscious even of the movements ve been excited in the posterior extremities.

ing can be more conclusive than such an experiment, in illus- of the fact that connection with the encephalon is necessary to on; and that movements, not only without volition, but even t consciousness, may be excited by stimulating the posterior its.

ct irritation of the spinal cord is capable of exciting these move- as much as when the stimulus is applied to the skin.

n the spinal cord is removed, all these motions cease; no ient of any kind, voluntary or involuntary, can then be excited, by directly stimulating the muscles, or the motor nerves by the muscles are supplied. Division of all the roots of the at their emergence from the cord produces precisely the same Under such circumstances no motion can be excited by stim- of the surface, nor by stimulation of the cord itself; and t may be regarded as an unequivocal proof that the nerves, in y actions, are propagators of the change produced by im- ns to or from the centres; and that in the physical nervous the stimulus acts not from one nerve to another directly, but the afferent nerve upon the centre, by which the motor nerve ted.

n these details we may draw the following conclusions:—1, e spinal cord, (we use the term in its simple anatomical sense, ntra-spinal nervous mass,) *in union with the brain*, is the instru- f sensation and voluntary motion to the trunk and extremities; the spinal cord may be the medium for the excitation of move- *independently* of volition or sensation, either by direct irritation

of its substance, or by the influence of a stimulus conveyed to it from some surface of the trunk or extremities by its nerves distributed upon that surface.

This latter office of the cord, although recognized by Whytt, Prochaska, Blane, and Flourens, had not attracted all the notice which its great importance merits, until the researches of Dr. Marshall Hall and Professor Müller drew attention to them; and to these physiologists, but especially to the former, much praise is due for the zealous and efficient manner in which they have investigated the subject.

The class of actions which take place in virtue of this power of the cord are so independent of all mental influence, and so purely physical in their cause, as well as in their nature, being provoked by a physical stimulus, and consisting essentially in a physical change in the centre, as well as in its afferent and efferent nerves, that they may be distinguished from those of volition and sensation, in which the mind has a necessary share, by being designated "physical." It has been already stated that Dr. Marshall Hall uses the not unobjectionable title of "excito-motory" in reference to these actions.

In general, when a stimulus is applied to the spinal cord, the actions which are excited by it are confined to a part which derives its nerves from that segment of the cord on which the stimulus falls. In some instances, however, parts supplied from other and even distant segments are thrown into action. Thus irritation of one leg will cause movements of one or both of the upper extremities; the introduction of a catheter into the urethra will sometime cause forcible contractions of the muscles of all the limbs. No doubt these effects are due to the extension of the irritation in the cord beyond the point first stimulated; and they may be regarded as proofs that that peculiar state of physical change which nervous irritation can excite in a centre may be propagated in the spinal cord, upwards, downwards, or sideways from the seat of the primary stimulation.

Disease affords some striking instances in confirmation of this remark.

A wound in the sole of the foot, or the ball of the thumb, or in some other situation favourable to the maintenance of prolonged irritation, is capable of exciting a particular region of the cord, from which the state of excitement spreads so as to involve not only the whole cord, but part of the medulla oblongata also; and in this state a large proportion of the motor nerves participate, so as to induce tonic contraction of the muscles they supply. This is the rationale of the development of that fearful malady called *tetanus*. It consists not in an inflammatory affection of the cord, or of its membranes, nor in congestion of them, but simply in a state of prolonged physical excitement, the natural polar force of the centre being greatly exalted, and kept so by the constant irritation propagated to it by the nerves of the wounded part.

In cases of paraplegia from disease of the spinal cord, even when the paralysis of sensation and of motion is complete, patients are

tormented with involuntary movements of the lower extremities at night, which not only prevent sleep, but occasion considerable pain and distress. Thus, parts which in their quiescent state are insensible, become painful in the state of excitement. The cause of this is no doubt to be found in a periodical exacerbation of the primary disease of the cord, and the extension of the state of excitement from the seat of the lesion to the whole cord; to that portion which is in connection with the brain, as well as to that which is below the lesion.

The rigid and contracted state of the muscles of paralyzed limbs, which frequently accompanies red softening of the brain, arises from the propagation of the excited state of the diseased part of the brain to that portion of the spinal cord which is connected with it, and from which the nerves of the paralyzed parts arise. These nerves likewise participate in the irritation of the cord, and thus keep the muscles in a continual state of active contraction. There is no organic lesion of the cord in these cases; its state of excitement is dependent on the cerebral irritation.

The convulsions of epilepsy arise from a similar cause, namely, irritation of the brain, involving the whole or a part of the spinal cord, and the nerves arising from it. In many instances the convulsions are limited to one-half of the body: in such cases there is generally lesion of the brain on one side, and the cerebral excitement is propagated only to one-half (the opposite) of the cord.

Some substances exert a peculiar influence upon the spinal cord, and throw it into a state of considerable polar excitement. Strychnine is the most energetic substance of this class. If a certain quantity of this drug be injected into the blood, or taken into the stomach of an animal, a state of general tetanus will quickly ensue, sensibility remaining unimpaired. The slightest touch upon any part of the surface, even a breath of wind blown upon it, will cause a general or partial convulsive movement. The whole extent of the cord is thrown into this polar state, and even the medulla oblongata is involved in it; whence the closed jaws, the spasmodic state of the facial muscles, the difficult deglutition. In this remarkable state of excitement it is curious to observe that the spinal cord is perfectly natural in point of structure, as far as our means of observation enable us to judge. We have examined some spinal cords, of animals which have died exhausted by the effects of the strychnine, but have always found the nerve-tubes and other elements of the cord exhibiting their natural appearance.

Opium is capable of creating a similar state of polarity in the cord. This is most conspicuous in cold-blooded animals; but no doubt it produces, in a much less degree, a similar effect in the warm-blooded classes. Hence there is an objection to the use of opium in large doses in cases of tetanus; and experience has shown its utter inefficacy when administered to a large amount.

This polar state of the cord, at least of a part of it, is sometimes developed naturally. The most remarkable example of this with which we are acquainted is in the case of the male frog, in the spring of the year, the season of copulation; the thumb on each hand be-

coming at this season considerably enlarged, as is well kn naturalists. This enlargement is caused principally by a consi development of the papillary structure of the skin which co so that large papillæ are formed all over it. A male frog at this has an irresistible propensity to cling to any object by seizin tween his anterior extremities. It is in this way he seizes up clings to the female, fixing his thumbs to each side of her ab and remaining there for weeks, until the ova have been con expelled. An effort of the will alone could not keep up such uninterruptedly for so long a time; yet so firm is the hold tha with difficulty be relaxed. Whatever is brought in the way thumbs will be caught by the forcible contraction of the limbs; and hence we often find frogs clinging blindly to a wood, or a dead fish, or some other substance which they may to meet with. If the finger be placed between the anterior e ties, they will grasp it firmly; nor will they relax their grasp un are separated by force. If the animal be decapitated whilst th is within grasp of its anterior extremities, they still continue on firmly. The posterior half of the body may be cut away, the anterior extremities will still cling to the finger; but imm that segment of the cord from which the anterior extremities their nerves has been removed all their motion ceases. This instinct, then, of the male frog, which naturalists have long is evidently connected with an exalted polarity of the cord, most manifest in the anterior extremities by reason of the enla of the thumb. It only exists during the period of sexual exci for at other periods the excitability of the anterior extremities siderably less than that of the posterior.

Nothing seems to control this polar state of the cord so eff as cold. Ice applied along the spine, or the cold douche, frequently employed with great advantage in cases of muscu turbance dependent on this polar state of the cord. We kno substance which, when introduced into the blood, effectuall this excited state. Conium and belladonna have been, in ou very useful in relieving the cramps and startings in paraplegi We have seen no marked benefit from hydrocyanic acid, a we have administered it freely: on the contrary, we fear that and the two former substances might, if given in large dos the contrary effect, and increase the polarity of the cord. C is, that animals poisoned by large doses of these drugs alway a state of general convulsion, and that in the instances wh have acted as poisons on the human subject, general con have come on a longer or shorter time before death.

Functions of the columns of the cord.—Having so far det the functions of the entire cord, the next question which our attention is, whether its columns have special function cordance with those of the separate roots of the nerves. Co proved that the anterior or motor roots were exclusively cc with the antero-lateral columns, and that the posterior or ones arose exclusively from the posterior columns, then ther

be good anatomical grounds for the doctrine so long erroneously prevalent, that the functions of these columns coincided with those of the roots, that the posterior columns were sensitive and the anterior motor: but nothing is more certain than that both roots are connected with the antero-lateral columns; and it is a matter of some doubt whether the posterior roots have any connection at all with the posterior columns. Hence, all that anatomy warrants us in stating is, that the antero-lateral columns are probably compound in function, both motor and sensitive. Respecting the office of the posterior columns little can be said. Are they sensitive? Were they so, it might be expected that they would exhibit an obvious enlargement at the situations which correspond to the origins of the largest sensitive nerves; but it is remarkable that the posterior columns exhibit little variation of size throughout the entire length of the cord. And it is not likely they can be motor, inasmuch as the apparent origin of the motor roots is so distinctly remote from them.

Comparative anatomy throws no light on this question. New and careful researches are much needed to determine the development of the posterior columns, and the exact relation which the posterior roots bear to them in different classes of animals.

Nor do we derive much positive knowledge from the researches of the morbid anatomist. Cases, indeed, are on record, which show that disease of the posterior columns does not necessarily destroy sensibility; that perfect sensibility is compatible with total destruction of the posterior columns in some particular region, the posterior roots remaining intact; and others have occurred in which sensibility has been impaired or destroyed, while the posterior columns remained perfectly healthy. In a remarkable case, related by Dr. Webster, there was complete paralysis of motion in the lower extremities, but sensibility remained;* yet there was complete destruction of the posterior columns in the lower part of the cervical region. Similar cases have been put on record by Mr. Stanley and by Dr. W. Budd. Dr. Nasse, of Bonn, refers to several cases of the same kind, observed by himself or others.† We have ourselves seen two cases in which the prominent symptom was great impairment of the motor power without injury to the sensitive; yet the seat of organic lesion in both was in the posterior columns of the cord. Such a case as that of Dr. Webster's appears to us to be conclusive, so far as the following proposition extends, namely, that sensation may be enjoyed in the inferior extremities *independently of the posterior columns*; and that, even if those columns be sensitive, there must be some other channel for the transmission of sensitive impressions besides them.

We are not aware of any well observed case in which the motor power persisted after extensive lesion of the antero-lateral columns; on the contrary, we believe it may be laid down as the general rule, that lesion of those columns always impairs both the motor and the sensitive functions to an extent proportionate to the amount of morbid structure.

* Med. Chir. Trans., vol. xxvi.
† Untersuchungen zur Physiologie und Pathologie. Bonn, 1835-36.

Pathological observations, then, appear to warrant the conclusion that the antero-lateral columns are compound in function, both sensitive and motor, but they do not justify us in attributing sensitive power to the posterior columns.

Direct experiments on the anterior and posterior columns of the cord are surrounded by difficulties, which embarrass the experimenter, and weaken the force of his inferences. The depth at which the cord is situate in most vertebrate animals, its extreme excitability, the intimate connection of its various columns with each other, so that one can scarcely be irritated without the participation of the others, the proximity of the roots of its nerves to each other, and the difficulty of irritating any portion of the cord itself without affecting either the anterior or the posterior roots, are great impediments to accurate experiments, and sufficiently explain the discrepancies which are apparent in the results of the various experiments which have been published. Moreover, the resultant phenomena, after experiments of this kind, are extremely difficult of interpretation, especially with reference to sensation. "The gradations of sensibility," remarks Dr. Nasse, "are almost imperceptible; the shades are so delicately and so intimately blended, that every attempt to determine the line of transition proves inadequate. There is a great deal of truth in an expression of Calmeil, that it is much easier to appreciate a hemiparalysis of motion than a hemiparalysis of sensation. If the anterior fasciculi of the cord possess sensibility, but only in a slight degree, the mere opening of the vertebral canal and laying bare the cord must cause such a degree of pain as would weaken or destroy the manifestations of sensibility in the anterior fasciculi. This has not been sufficiently attended to by experimenters. Again the practice of first irritating the posterior fasciculi, and afterwards the anterior, must have had considerable effect in producing the same alteration. It is plain that, in this way, the relations which the anterior fasciculi bear to sensation must be greatly obscured; yet with the exception of some few experiments, this has been the order of proceeding generally adopted."*

All those who have made experiments with the view of ascertaining the functions of the columns of the cord, agree in stating that irritation of the anterior columns was attended with more or less movement. The results of stimulation of the posterior columns, however, have been differently stated by various observers: many found that it was attended with the excitation of motion; and others, that the least irritation of the posterior columns excited pain. M. Longet, who is among the latest experimenters on this subject, observes, that motions result from irritation of the posterior columns only when the experiment has been made immediately after the transverse division of the cord, and he refers such motions to the excitability of the cord itself. After a little time, however, this subsides; and then M. Longet has been able to pass the galvanic current through each or both of the posterior columns, without exciting any motions when the lower segment of the

* Loc. cit.; quoted from an abstract in the Brit. and For. Med. Review, vol. iv.

cord was acted upon, but causing pain, as evinced by loud cries and writhing of the body, when the upper segment was tried. Dr. Baly's experiments on tortoises showed that movements might be excited whether the anterior or posterior columns were irritated,* much stronger motions being excited by the posterior than by the anterior columns.

It is clear, then, that we must not draw any other conclusion from experiment than that the antero-lateral columns appear to be motor in their function. Respecting their sensitive power we gain no information from this source: and it must be confessed that our knowledge is no more advanced by it as regards the posterior columns.

We are much disposed to think that the antero-lateral columns are the centres of the main actions of the cord, whether mental or physical. Both roots of the nerves are connected with these columns, and therefore fibres of sensation and of motion must be found in them. These columns are always proportionate to the nerves which arise from them: they enlarge when the nerves are large, and contract when the nerves diminish in size. The posterior columns, on the other hand, are of uniform dimension throughout nearly the entire length of the cord, although the posterior roots of the nerves exhibit considerable difference in point of size in different regions.

We venture to suggest that the posterior columns may have a function different from any hitherto assigned to them. They may be in part commissural between the various segments of the cord, and in part subservient to the function of the cerebellum in regulating and co-ordinating the movements necessary for perfect locomotion.

The analogy of the brain, in which the various segments are connected by longitudinal commissures, suggests the probable existence of fibres similar in office for the spinal cord. If we admit such fibres to be necessary to ensure harmony of action between the several segments of the encephalon, there are as good grounds for supposing their existence in the cord, which in reality may be regarded as consisting of a number of ganglia, each a centre of innervation to its proper segment of the body, and therefore requiring some special connecting fibres to secure consentaneous action with the rest.

The attribute of locomotive power rests upon the connection of the osterior columns with the cerebellum, and the probable influence of iat organ over locomotion. If the cerebellum be the regulator of comotive actions, it seems reasonable to suppose that those columns the cord which mainly pass into it, should enjoy a similar function; at, as they are the principal medium through which the cerebellum brought into connection with the cord, it must be through their nstituent fibres that the cerebellum exerts its influence on the nerves the lower extremities, and of other parts concerned in the locomore function.

The nearly uniform size of the posterior columns in the different gions of the cord has been already remarked as unfavourable to eir being channels of sensation. But this anatomical fact may be duced as a good argument in support of the hypothesis which we

* See his translation of Müller's Physiology, Second Edit., p. 796.

are now discussing. It is worthy of notice that these columns experience no marked diminution in size until the large sacral nerves, which furnish the principal nerves of the lower extremities, begin to come off.

In examining a transverse section of the lumbar region of the cord, we observe a great predominance of its central gray matter; the posterior columns appear large, and the antero-lateral columns inadequate in proportion to the large roots of nerves which emerge from it. Now, an analysis of the locomotive actions renders it highly probable that they are partly of a volitional character and partly dependent on the inherent power of that segment of the cord from which the lower extremities derive their nerves. In progression there are two objects to be attained,—to support the centre of gravity of the body, and to propel it onward; the former object requiring, first, that the muscles of the lower extremities, the pillars of support to the trunk, should be well contracted, in a degree proportionate to the weight they have to sustain. Those actions by which the trunk is balanced upon the limbs, and by which the movements of progression are effected, are subsequently called into play through mental influence. The contraction of the muscles of the limbs seems well provided for in an arrangement for the development of nervous power by a stimulus propagated *to* the centre. This stimulus is afforded by the application of the soles of the feet to the ground; it is therefore proportionate to the weight which presses them downwards. It is well known that physical nervous actions are more developed in the lower than in the upper extremities, and the surface of the sole of the foot is well adapted for the reception of sensitive impressions. No object can be assigned for this peculiarity, unless it have reference to the locomotive actions; and the great development of the vesicular matter in this region betokens the frequent and energetic evolution of the nervous force. All the structural arrangements necessary for this purpose are found in the antero-lateral columns. The posterior columns come into play in balancing the trunk, and in harmonizing its movements with those of the lower extremities.

Experiment, while it fails to elucidate the function of the posterior columns, exhibits nothing in opposition to the views we have expressed. It is not to be expected that commissural and co-ordinating fibres should react with stimuli similarly to fibres of voluntary motion.

We think that the phenomena of disease may be referred to in support of our view. In many cases where the principal symptom has been a gradually increasing difficulty of walking, the posterior columns have been the seat of disease. We may notice two kinds of paralysis of motion, distinguished respectively by impairment or loss of voluntary motion, and of the power of co-ordinating movements. In the latter form, while the voluntary powers are considerable, the patient walks with great difficulty, and a gait so tottering that his centre of gravity is easily displaced. These cases are generally of the most chronic kind, and many of them go on from day to day without any increase of the disease or improvement in their con-

dition. In two examples of this variety we ventured to predict disease of the posterior columns of the cord: and this was found to exist on a post-mortem inspection. All cases on record, which we have had the opportunity of examining, in which the posterior columns were the seat of disease, began by evincing more or less disturbance of the locomotive powers; and it seems to us that the degree to which sensibility may become affected will greatly depend upon the extent to which the *posterior roots* of the nerves are involved in the disease.

The hypothesis, then, which we are most disposed to adopt, is the following:—That *the antero-lateral columns of the spinal cord with the gray matter* are, in connection with the brain, the recipients of sensitive impressions and volitional impulses, and that they are the centres of the independent or physical nervous actions of the cord; and that *the posterior columns* propagate the influence of that part of the encephalon which combines with the nerves of volition to regulate the locomotive powers, and serve as commissures in harmonizing the actions of the several segments of the cord.

What is the *mechanism* of these actions of the spinal cord—mental, physical, locomotive? This is a problem of the highest interest, bearing upon the mechanism by which nervous power developed in any nervous centre, as well as in the cord, is capable of affecting peripheral parts; and it is on that account well deserving the most patient investigation.

We assume, as necessary postulates, preliminary to the discussion of this question, the two following propositions:—1. That the brain, or some part of it, is the sensorium commune; or in other words, that mental nervous actions (acts of volition and sensation) cannot take place without the brain. 2. That the vesicular is the truly dynamic nervous matter, the source of all nervous power.*

The following hypotheses have been proposed in explanation of these actions.

* The first of these postulates will be considered farther on in this chapter. The second appears to us to have a sufficiently firm foundation to warrant us in assuming its correctness, for the sake of arguing the important question referred to in the text. We shall state briefly here the proofs that the association of the vesicular and fibrous matter is necessary to the development of nervous force.

1. Nerves, when separated for a time from the nervous centre, lose all power of stimulating their muscles to contraction. No irritation, mechanical or electrical, is sufficient to excite them. If a nerve be divided some distance from the centre, the peripheral portion, will, after a time, waste, and lose all power of developing nervous force; but the central portion, which remains in connection with the centre, retains its nutrition and its vital properties unimpaired.

2. All nervous centres contain vesicular matter, with which nervous fibres freely intermix.

3. The power of a nervous centre appears to be proportionate to the quantity of its vesicular matter. This is well exemplified in the cerebral convolutions, the vesicular surface of which is always in the direct proportion of the development of mental power; or, in general terms, *the gray matter increases in the exact ratio of the nervous energy*. (Grainger.)

4. All nerves appear to arise from vesicular matter. Stilling represents special accumulations of vesicular matter at the origins of the nerves of the medulla oblongata.

5. Nerves, whose power is exalted for some special purpose, have an increased quantity of gray matter at their origin, of which the electric lobe in the torpedo, connected with the origins of the fifth and eighth pairs of nerves, is an extraordinary instance.—See Mr. Grainger's excellent work on the Spinal Cord, pp. 18–21.

1. The various muscles and sentient surfaces of the body are connected with the brain by nerve-fibres, which pass from the one to the other. Those fibres destined for, or proceeding from, the trunk to the brain pass along the spinal cord, so that that organ is in great part no more than a bundle of nerve-fibres going to and from the brain. These fibres are specially for sensation and voluntary motion.

But, in addition to these, there is another class of fibres proper to the spinal cord and to its intra-cranial continuation, which form a connection with the gray matter of the cord. Of these fibres, some are afferent or incident, others efferent or reflex, and these two kinds have an immediate but unknown relation to each other, so that each afferent nerve has its proper efferent one, the former being *excitor*, the latter *motor*. The aggregate of these fibres together with the gray matter constitutes the *true spinal cord* of Dr. Marshall Hall, which is not limited to the spinal canal, but passes up into the cranium as far as the crura cerebri. These fibres are quite independent of those of sensation and volition, and of the sensorium commune. Although bound up with sensitive and motor fibres, they are not affected by them, and they maintain their separate course in the nerves as well as in the centres. Such is the hypothesis of an *excito-motory system of nerves*, and of a *true spinal cord*, the centre of all *physical* nervous actions, which has been proposed and most ably advocated by Dr. Marshall Hall.

2. The fibres of sensation and volition proceed to and from some part or parts of the intra-cranial mass. Those which are distributed to the trunk pass along the spinal cord, separating from it with the various roots of the nerves, and in their course within the spine they mingle more or less with the gray matter. There are no other fibres but these (save the commissural), and they are sufficient to manifest the physical as well as the mental acts. Nerves of sensation are capable of exciting nerves of motion which are in their vicinity; and they may produce this effect even when the spinal cord has been severed from the brain, for their relation to the gray matter of the cord is such that their state of excitement is readily conveyed to it. This explanation tallies with the views of Whytt, Prochaska, and the other physiologists who had recognized the existence of a class of actions produced by the influence of sensitive upon motor nerves.

3. According to a third hypothesis, it is assumed that all the spinal and encephalic nerves, of whatever function, are implanted in the gray matter of the segments of the cerebro-spinal centre with which they are severally connected, and do not pass beyond them. The segments are connected with each other through the continuity of the gray matter from one to another, and through the medium of commissural fibres which pass between them. Through these means, motor or sensitive impulses are propagated from segment to segment; and a stimulus conveyed to any segment from the periphery may either simultaneously affect the brain and cause a sensation, or be reflected upon the motor nerves of that segment and stimulate their muscles to contract.

The first hypothesis, which assumes the existence of a distinct series of incident and reflex nerves for the physical nervous actions, offers a very beautiful explanation of those cases in which, while sensation is entirely destroyed, movements may yet be excited without the consciousness of the individual. In such cases it is supposed that the fibres of sensation and volition are alone paralyzed, but that those of the true spinal cord remain free from injury or disease, and therefore competent to perform their functions. Sometimes, however, these fibres participate in the general shock which the spinal cord or brain experiences at the onset of disease or accident, and therefore reflex movements are not to be excited in all cases in which the influence of the brain has been cut off by disease of that organ, or of the cord itself.

This hypothesis has very much to commend it; and not the least argument in its favour is that drawn from the compound nature of spinal nerves, as proved by Bell, in which filaments of very different endowments are bound together in the same sheath. If it be proved that filaments of sensation and of motion may be thus tied together, it is not going too far to conjecture the existence of another series of fibres of distinct function.

The movements of decapitated animals, of parts in connection with small segments of the spinal cord, of limbs paralyzed to sensation and voluntary motion from diseased brain or spinal cord, are satisfactorily explained by this hypothesis. But there are two phenomena familiar to those who observe disease with a knowledge of the many interesting discussions now going on upon the nervous system, which are not explained by it: these are, the movements which may be excited by mental emotion in limbs paralyzed to the influence of the will, and the total paralysis of the sphincter ani, which frequently accompanies diseased brain, whilst, at the same time, the limbs are only affected to a partial degree.

Cases occur sometimes in which hemiplegia arises from an apoplectic clot or other destructive lesion in one hemisphere of the brain. The arm and leg, or either of them, are completely removed from the influence of the will; yet, occasionally, under the influence of some sudden emotion, fear, joy, surprise, the palsied limb is raised involuntarily with considerable force.* Mental emotions probably affect some part of the brain: if the only communication between the brain and the limbs be by the fibres of sensation and volition, it is impossible to understand how, in such a case, the emotional influence could be conveyed through a channel which has long been stopped. If we are to adopt Dr. Hall's theory, it will be necessary to suppose, with Dr. Carpenter, the existence of certain *emotional* fibres to explain the phenomena of this particular case. But it is difficult to admit the existence of three orders of fibres in each muscle, which, to be effective, must have the same relation to the component elements of the muscle. It is impossible to imagine how each order of fibre

* Even so slight a cause as yawning, which is an action of emotional character, will excite a palsied limb In the case of a patient now in King's College Hospital with very complete hemiplegia, the arm is raised involuntarily every time he yawns.

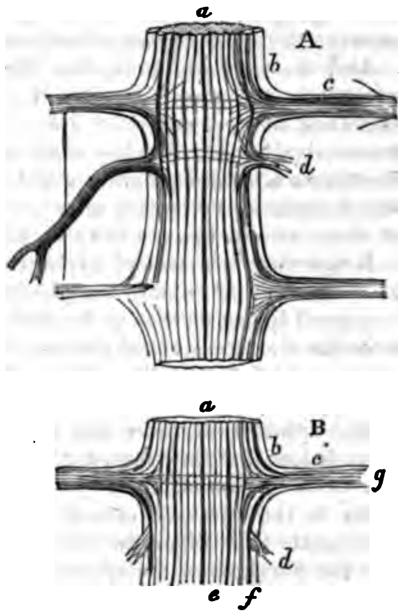
should comport itself with reference to the other two, so that their actions may not interfere. Nor can any one fail to perceive that the emotional fibres must be infinitely less frequently employed than the others, and in some individuals, so little called into action, as to expose the fibres greatly to the risk of atrophy for want of use.

Paralysis of the sphincter ani is most frequently produced by disease of the spinal cord; but it is by no means a rare accompaniment of diseased brain, and generally indicates a lesion of grave import. Now, such a lesion is always accompanied with paralysis, chiefly of the hemiplegic kind, but not necessarily complete; on the contrary, in several such cases we have seen distinct reflex movements, indicating that although the brain's influence was withheld from the limbs, that of the cord was not. If then the cord be sufficiently free from morbid depression to allow of reflex movements taking place in the inferior limbs, why is the sphincter so completely paralyzed that it offers not the slightest resistance to the introduction of the finger into the anus? It is admitted that the sphincter is under the influence of the will; according to Dr. Hall's theory, this must be through special fibres of volition distributed to it: but it is also under the influence of the spinal cord, as the limbs are; yet, if the cerebral fibres be diseased, there seems no reason why the influence of the cord upon it should be at the same time destroyed. A cerebral lesion ought not to affect the sphincter further than to destroy the control of the will upon it, unless its depressing influence extend to the whole cord, and in such a case there ought to be complete paralysis of the limbs likewise.

These are not unimportant pathological objections to this theory: to them we must add the fact, that this view wants the support of anatomy. However disposed we may be to admit the existence of fibres implanted solely in the gray matter of the cord, it must be confessed that it is as yet far from being proved that either such fibres, or those which are continued up into the brain, exist in the cord of vertebrata, or in its analogue of the invertebrata. Dr. Carpenter and Mr. Newport, it is true, affirm that they have demonstrated the two sets of fibres in insects—the *sensori-volitional*, and the *excito-motory*. The former author describes the nerves of articulata as consisting of fibres derived from two sources—namely, the anterior or cerebral ganglion, and the ganglion of that segment of the body to which they belong. Those fibres which are connected with the brain, he states, pass down along the dorsal surface of the ganglionic chain, and are fibres of sensation and voluntary motion; those which are immediately implanted in the ganglia are excito-motory. Mr. Newport, in his recent able and elaborate description of the nervous system of Myriapoda, thinks that he shows a somewhat similar arrangement in those animals. The ganglionic chain has on its dorsal surface a pair of columns, *superior longitudinal fibres*, which pass over the ganglia, sending a few fibres to mingle with them, or with an inferior pair of longitudinal columns. These latter, the *inferior longitudinal fibres*, are placed along the abdominal surface of the ganglionic chain, and are intimately connected with the ganglia. In the intervals between the ganglia these two columns lie in close juxtaposition, separated

only by some transverse fibres. The inferior columns appear, as Mr. Newport states, to receive fibres from the superior columns, and probably to send some to them, "thus decussating each other in the middle substance of the cord, where these two longitudinal series are in close apposition; since it is almost impossible, even in the large nervous cord of Scolopendra, to separate these two tracts from each other, although their distinctness is evinced in their relative size and longitudinal lines of separation."* The ganglia, then, are placed between these two columns, the inferior pair being intimately connected with them. Almost the whole of the fibres of the inferior longitudinal series are traceable, says Mr. Newport, in the Iulidæ, directly through each enlargement of the cord which they mainly assist to form. Two other sets of fibres are distinguished by this anatomist in these animals, which do not take a longitudinal course. These are, first, the *commissural* fibres, which pass transversely between corresponding nerves of opposite sides of the body; and secondly, *the fibres of reinforcement of the cord*, which communicate between nerves of the same side of the body, passing from a nerve which arises from a superior ganglion to one that comes from an inferior one. These nerves do not appear to penetrate the cord: judging from Mr. Newport's description, they merely pass from nerve to nerve, forming loops which are convex towards the cord, and constitute the lateral portion of the cord in the intervals between the points of nergence of the nerves with hich they are connected. he two sets of *transverse* and *teral* fibres agree in the fact

Fig. 73.



Upper and under surfaces of a portion of the cord in Spirostreptus.—After Newport.
A. Under surface. B. Upper surface.
a. Inferior longitudinal fibres. *e.* Superior longitudinal fibres. *f.* Fibres of reinforcement, also seen at *b* and *c.* *g.* Commissural fibres, also seen at *d*, A.

at they do not pass upwards to the brain; but of their connection ith the cord nothing is known. Indeed it is by no means apparent at the lateral fibres form any junction with the vesicular matter of e cord or with any other than peripheral portions of the nervous stem; Mr. Newport's researches show only that they are in juxtasition with the margins of the cord, but we cannot infer from them at they mingle with its elements. Moreover it is far from being oved that the longitudinal fibres pass up to the brain. The brain,

* Phil. Trans., 1844.

indeed, is not necessarily the largest of the ganglia, and it must be admitted to bear a most inadequate proportion to the number of longitudinal fibres. Let any one compare the size of the cerebral ganglia of the scorpion (as figured by Mr. Newport) with the size of the animal and that of its cord, and it will be evident to him how disproportionately small such a centre is to the number of sensori-volitional fibres which must be distributed over so large a surface, and to so many muscles. When too it is stated that the observations of these physiologists were made with low powers of the microscope, it must be confessed that there is as much obscurity as to the origin of the nerves in invertebrata as in vertebrata; and that we are not yet entitled to conclude that the existence of two orders of fibres has been actually demonstrated in the former class. Anatomy offers no objection to the hypothesis that the roots of the nerves are implanted in the ganglia, and that the longitudinal fibres act as commissures between different segments (both adjacent and remote) of the cord.

And we may add here, that Mr. Newport's experiments on the myriapods and other articulata throw no light on the question of the existence of two orders of fibres; nor do they add anything to our knowledge beyond the important fact, that actions take place in invertebrata after decapitation which are of the same nature with those which occur in vertebrata after a similar mutilation. The mechanism of these actions has not been at all elucidated by these experiments.

Respecting the second hypothesis, we must remark, that it is just as competent to explain the phenomena of decapitated animals, and paralyzed limbs, as that of Dr. Hall, and that it receives some support from the almost universal concurrence of sensation with those normal actions which Dr. Hall would attribute to excito-motory fibres. If it be supposed that these fibres have a certain relation to the gray matter of the spinal cord, there can be no good reason against the further supposition, that they may continue to be affected by it after the brain has been separated from the cord. This hypothesis, however, is liable to the same objections as that of excito-motory fibres: it is inadequate to explain the influence of emotion on paralyzed limbs, and the paralysis of the sphincters; and, moreover, it cannot be considered to be proved that fibres are continued up directly from the spinal nerves to the brain. The fibres of the anterior pyramids, no doubt, are true cerebro-spinal fibres; but they may be merely commissural. We have no evidence that fibres of the lumbar region of the cord pass into the brain. The longitudinal course of fibres in the spinal cord affords no proof that those fibres pass into the brain, for it is well known that most of the nerves take a very oblique course from their point of separation from the cord to their emergence from the spinal canal; and it is probable that the fibres continue their obliquity in the cord itself, so that their real origin would be higher up than their apparent one. This great length of oblique course gives to the fibre the appearance of being strictly longitudinal, whereas it may be implanted in the gray matter of the cord.

The third hypothesis appears to us to admit of fewer objections than either of the others, and to be more consonant with what seems

be the correct anatomy of the cord. It supposes that the mechanism of a mental and that of a physical nervous action are essentially the same, differing only in the nature and the mode of application of the stimulus. The same *afferent* and *efferent* fibres are exerted in the one case as in the other; the former acting as *sensitive* or *excitor*, or both; the latter as channels for *voluntary*, *emotional* or strictly *physical* impulses to motion.

This hypothesis is content to assume that fibres of sensation and voluntary motion do not pass beyond that particular segment of the cord with which they are connected; and that each segment of the cord communicates readily with the brain through the horns of gray matter, or through commissural fibres which pass between the segments of the cord, and from the upper segment of the latter to the brain. The anatomy of the cord, so far as our present knowledge extends, is favourable to this hypothesis, for it is much more probable that all the roots of the spinal nerves are implanted in their proper segments of the cord, than that some pass up to the brain, and others remain in the cord. The varying dimensions of the cord, at different regions, disincline us to admit the existence of fibres which are continued up into the brain from the spinal nerves. It is impossible to understand the great superiority of size of the lumbar portion over the dorsal segment of the cord, if we admit that this latter segment contains, in addition to its own fibres, (sensori-volitional and excito-motory,) the sensori-volitional fibres of the lumbar swelling also. The fibres of sensation and volition, which pass to the great lumbar and sacral nerves, could, in that case, be only extremely few in proportion to the excito-motory ones; nor would they seem adequate to the motor and sensitive endowments of the lower extremities; where it must be admitted volition and sensation enjoy an extensive sway. Moreover, it may be stated that the great size of the lumbar swelling depends mainly on the large quantity of vesicular matter which exists in it; and the total amount of fibrous matter is hardly so much as might be expected to exist if the lower extremities and the pelvis were supplied with both sensori-volitional and excito-motory fibres.

It is very generally admitted that the only channel by which the will can influence the spinal cord is through the fibres of the anterior pyramids, the greater number of which decussate each other along the median line, as already explained in page 241. The most frequent pathological phenomena favour this view. Now it is in the highest degree improbable that these fibres, occupying so small a space as they do, should form the aggregate of the volitional fibres (still less the sensori-volitional fibres) of the trunk and extremities. It seems to us much more reasonable to regard the fibres of the pyramids in the light of commissures, connecting the gray matter of the cord with that of the brain, and serving to associate these two great divisions of the cerebro-spinal centre in the voluntary, if not in all the mental nervous actions.

The mechanism of a voluntary action, in parts, supplied with spinal nerves, would be, according to this hypothesis, as follows: The impulse of volition, primarily excited in the brain, acts at the same time

upon the gray matter of the cord (its anterior horn), which in virtue of its association with the former, by means of the fibres of the anterior pyramids, becomes part and parcel of the organ of the will, and therefore as distinctly amenable to acts of the mind as that portion which is contained within the cranium. If we destroy the commissural connection through the pyramidal fibres, the spinal cord ceases to take part in mental actions; or, if that connection be only partially destroyed, that portion of the cord which the injured fibres had associated with the brain, is no longer influenced by the mind. Again, if the seat of volition in the brain be diseased, the cord, or part of it, participates in the effects of the disease, as far as regards voluntary actions. That it is not too much to ascribe such power to the pyramidal fibres, appears reasonable, if we consider how the fibres of the corpus callosum, and perhaps other transverse commissures, so connect the hemispheres and other parts of the brain that the separate divisions of a double organ act harmoniously in connection with the operations of a single mind; or that, conversely, two impressions from one and the same source on a double sentient organ are perceived as single by the mind.

An objection to this explanation will readily be raised, that the excitation of the anterior horn of the gray matter, in the way stated, does not explain the remarkable power which the will has of *limiting* its action to one or two, or a particular class of muscles. We reply to this, however, that there can be no reason for denying to the mind the faculty of concentrating its action upon a particular series of the elementary parts of the vesicular matter, or even upon one or more vesicles, if we admit that it can direct its influence to one or more individual fibres, as the advocates of the first and second hypotheses do. If, indeed, we admit the one, we must admit the other; for whether the primary excitation of a fibre take place in the encephalon or in the spinal cord, the part first affected must probably be (according to our second postulate) one or more vesicles of the gray substance.

The series of changes which would develop a sensation, admits of the following explanation: A stimulus applied to some part of the trunk or extremities is propagated by the sensitive nerves to the posterior horn of the gray matter of the spinal cord, and from the junction of this part with the brain either through the direct continuity of the vesicular matter of the cord with that of the centre of sensations, or through longitudinal commissural fibres, analogous to, or even perhaps forming part of, the anterior pyramids, this organ is simultaneously affected. To this likewise it will be objected, that the limitation of sensations is not sufficiently explained. But the reply is obvious: the *intensity* and *kind* of sensation depend upon the nature of the primary stimulus at the surface; the *extent* upon the number of fibres there stimulated. Wherever these fibres form their proper organic connection with the vesicular matter, that matter will participate in their change to an extent proportionate to the number of fibres stimulated, and with an intensity commensurate with the force of the primary stimulus. It is not necessary to the development of

sensation that the fibre stimulated should be implanted directly in the brain; if it be connected with this centre through the medium of vesicular matter of the same character as that which is found in it or through commissural fibres, all conditions necessary for the development and propagation of nervous force would appear to be fulfilled. It must not be supposed, however, that in making this statement we mean to assign the spinal cord to be the *seat* of sensation; all we assert is, that the posterior horns of its gray matter, as being the part in which the sensitive roots are implanted, participate largely in the mechanism of sensation; and that by their union with the brain they become, *pro tanto*, a part of the centre of sensation, so long as that union is unimpaired.

This hypothesis offers an explanation of the hitherto unexplained phenomenon of impaired sensation on that side of the body which is opposite to the seat of cerebral lesion. If we regard the anterior pyramids as commissures between the sensitive, as well as between the motor portions of the cerebro-spinal centre, it will be obvious that the posterior horns of the spinal gray matter on the right side will be associated with the left centre of sensation in the brain, and *vice versâ*.

And we gain, moreover, an explanation of the almost universal association of sensation with reflex or physical actions. The excitor nerves of these actions being the same as the sensitive nerves, the impression conveyed by them is calculated at once to excite motion and sensation. Were it not for the controlling influence of the will, all sensitive impressions made through the spinal cord would likewise be accompanied by corresponding movements. When the spinal cord has been excited by strychnine, the physical power prevails over the mental, and the will ceases to be able to control the movements excited by impressions through sensitive nerves.

A highly important argument in favour of this view is derived from the marked difference of structure of the anterior and posterior horns of the spinal vesicular matter. The anterior and posterior roots of the nerves exhibit no difference of structure; no anatomist could distinguish in a compound nerve the sensitive from the motor filaments. The vesicular matter, however, in the anterior horn, contains large caudate vesicles of a remarkable and peculiar kind (fig. 56, p. 198); whilst that in the posterior horn resembles very much the vesicular matter of the cerebral convolutions, and of other parts of the cerebrum, and does not contain caudate vesicles, except near the base. Here, then, we find associated with the well-attested difference in the *functions* of the anterior and posterior roots, a striking difference in the *structure* of the anterior and posterior horns of gray matter.

This hypothesis is adequate to the explanation of the influence of emotion or limbs paralyzed as to voluntary movement, without the necessity of assuming the existence of a totally distinct series of fibres for this class of actions. The change in the brain, excited by emotion, is propagated to the spinal gray matter, in a manner analogous to that in which the influence of the will is brought to bear on it. It thus

affects the ordinary motor fibres; and, therefore, the movements which are produced by emotion resemble very closely those excited by the will.

This hypothesis suggests a very obvious explanation of the kind of antagonism which appears to exist between voluntary and reflex actions. It is well known that in health the will can in a great degree control and prevent the development of reflex actions in the lower extremities. If one be paralyzed, as in hemiplegia, from disease of the brain, whilst the other remains sound, a very striking contrast is sometimes to be observed between the two limbs. On stimulating the sole of the foot in the diseased limb, reflex actions are readily produced; but, on applying the same stimulus to the same part of the sound limb, no such movements occur, the patient being conscious of the application of the stimulus, but resisting the tendency to action which it produces. The will has lost its control over the diseased limb; but, as the motor nerves and the spinal gray matter are sound, actions may still be excited through a stimulus from the periphery; and, the more complete has been the separation of the brain's influence from the cord, the more perfect will be the reflex actions. Hence we frequently find these movements more perfect in cases where sensation as well as voluntary power is destroyed in a limb, than where the latter only has ceased.

It may be here remarked, that movements which at one time are voluntary, may at another time be physical. If the influence of the will be suspended for a brief period, stimulation of the surface will produce the same movements which previously were excited by voluntary impulse. Thus, tickling the soles of the feet, in a person asleep, excites movements which doubtless are of the reflex kind; but the same stimulation, in a person awake, will give rise to precisely the same movements, which he is conscious are, at least in a great degree, voluntary.

Some reflex actions are imperfectly controllable by the will; of which the contraction of the pupil, and the movement of deglutition at the isthmus faucium, are examples. It is remarkable, however, that the will may give rise to these actions by associating others with them: the pupil may be contracted at will, by directing the eye inwards; and the fauces may be contracted by bringing some saliva in contact with them. In the latter case the stimulus of volition alone is not sufficient to excite the movement; the addition of a physical stimulus is likewise necessary: and, in the former, the excitability of the fibres of the third nerve by a mental stimulus may be materially modified by their re-association with vesicular matter in the ophthalmic ganglion.

There is nothing in this hypothesis repugnant to the idea, that certain nerves may be connected in the centres with masses of vesicular matter over which the will usually exercises little or no control, and which, perhaps, have but a slight connection with the brain through commissural fibres. Facts like those instanced in the preceding paragraphs may be accounted for on such a supposition as this. This supposition may be required to explain some of the actions of nerves

connected with the medulla oblongata, the vagus for instance, but certainly not of spinal nerves.

It is probable that in many actions the double stimulus, mental and physical, is necessary to their perfect development. The former is excited by the mind acting on the vesicular matter; the latter is propagated at the same time, by sensitive nerves, to the same region of vesicular matter; and both simultaneously influence the same motor fibres. In locomotion, it seems probable that this is the case: the degree of contraction of the muscles necessary to maintain the superincumbent weight is obtained by the physical stimulus of pressure against the soles of the feet; but the movements of the limbs, and the harmonizing association of the muscular actions, are effected by mental influence. The pressure against the soles is felt, however; and the same nerve-fibres which excite the sensation, stimulate the vesicular matter in which the motor nerves are implanted. In many actions of familiar occurrence, the voluntary effort is greatly enhanced by the simultaneous application of a physical stimulus to a part of the surface which is supplied with nerves from the same region of the cord. The horseman feels more secure when his legs are in close contact with the horse's flank. We gain a much firmer hold of an object which adapts itself well to the palmar surface of the hand, than of one which, although of no greater bulk, is yet so irregular in surface as not to allow of such intimate contact with the palm. Closure of the eyelids in winking is an action of similar kind, resulting from a physical stimulus, which, in the perfect state of the cerebro-spinal centre, produces sensation, and excites motion which is at once the result of the physical impression, and of the exercise of volition provoked by the sensation. Every one must be conscious that he exercises considerable control over the movements of his eyelids, and that it requires a great effort to prevent winking for a certain period. At length, however, the physical impression, arising from the contact of air with the conjunctiva, and the diminution of temperature from evaporation on the surface of that membrane, which at first caused but a slight sensation, produces *pain;* the physical stimulus overcomes the mental resistance, and causes contraction of the orbicular muscle. And it may be remarked further, that the closure of the lids by voluntary effort is much more powerful if a stimulus be applied at the same time to the conjunctival surface, than if left solely to the exercise of the will.

In the action just referred to, as well as in all other instances of reflex actions which the will can prevent, no satisfactory explanation of this controlling power of the mind can be given by Dr. Hall's hypothesis—Do the volitional fibres exceed in number the excito-motory? If this were admitted, then we could understand that an excito-motory act might be prevented by substituting a voluntary act for it; but, in the cases in question, the mind prevents action altogether, notwithstanding the exciting influence of the impression. The true explanation seems to be, that the mind can exert upon the vesicular matter a power which can prevent the exercise of that change,

or neutralize the change, without which the motor fibres will not be affected by a physical stimulus.

Reflex actions are more manifest in some situations than others: thus, in cases of hemiplegia from diseased brain, they are generally very obvious in the lower extremity, but totally absent in the upper. This, the advocates of the excito-motory theory ascribe to a paucity of excito-motory fibres in the latter limb, and to a larger amount of them in the former. Or, it has been attributed to the greater and more enduring influence of shock upon that segment of the cord from which the nerves of the upper extremities arise, as nearer the seat of lesion, than upon the lumbar segment. But another explanation appears to us equally satisfactory, and more accordant with other phenomena. A certain *disposition of the nerves upon the tegumentary surface is as necessary for the development of reflex actions as of sensations;* and these movements will be more or less easily manifested, according as this organization of the nerves on the surface is more or less perfect.

That disposition of the cutaneous nerves which renders the surface easily excitable by titillation seems most favourable to the development of these actions. Hence, there is no place where they are more readily excited than in the lower extremities by stimulating the soles of the feet or the intervals between the toes, both of which situations are highly susceptible of titillation. At the isthmus faucium the slightest touch on the surface excites a movement of deglutition; and this touch, at the same time, produces a very peculiar sensation of tickling, quite distinct from that which may be excited at other parts of the pharynx, or mouth. When this part of the mucous membrane is in a state of irritation as an effect of coryza, this tickling sensation is present, and repeated acts of swallowing are provoked.

Two facts may be stated here, which illustrate the position we have laid down respecting the necessity of a certain disposition of the nerves *on the tegumental surface*, for the development of reflex actions. The first is one which has been noticed by Volkmann, and which we had ourselves repeatedly observed, namely, that in frogs, and other animals, reflex actions are readily excited by stimulating the feet; but irritating the posterior roots of the spinal nerves, which supply those parts, is not sufficient for this purpose. In experiments repeatedly made upon the posterior roots of the nerves we have very rarely seen movements excited whilst they have been subjected to irritation, and the recorded statements of all modern experimenters agree in the main with this statement. The second fact is this: in the male frog the development of a papillary structure on the skin of the thumb seems to have reference to the excitation of the physical power of the cord, to enable the animal to grasp the female without the necessity of a prolonged exercise of volition. Stimulating the fingers will scarcely produce reflex actions, but the slightest touch to the enlarged thumb will cause the animal to assume the attitude of grasping. If the papillæ be shaved off the thumb, its power of exciting these actions is instantly lost.

When the polarity of the cord is greatly excited by strychnine or

ither substances, or when tetanus exists, all parts of the surface are qually capable of exciting reflex actions. The least touch will cause hem, not only in the limb touched, but in all that side of the trunk, r even throughout the whole body. So general is the excitation, hat the least impression made on the peripheral extremity of a sensiive nerve in any part of the body is instantly converted into muscular pasm, more or less general. A slight current of air, in tetanus, s sufficient to excite general spasm. Müller remarks, that, in such tates of the cord, the reflex actions excited by stimulating the nerves hemselves are much less than those produced by excitation of the urface.

The readiness with which a physical change, induced in one part f the centre, is propagated to others, whether above or below it, is lue no doubt to the vesicular matter. An experiment made by Van Deen illustrates this statement. If, in an animal poisoned by strychine, the cord be divided in its entire length along the median line, eaving only a slight bridge of gray matter, stimuli applied to any part of the surface will exhibit as extensive reactions as if the cord were entire. It is evident that the only medium of communication between the opposite halves, must be the small portion of vesicular matter left undivided.

Impressions conveyed to the cord by the posterior roots of any of its nerves, may be reflected to the corresponding motor nerves and cause movement, or may extend irregularly along the posterior horns f gray matter, and stimulate the nerves implanted in them, and thus give rise to new sensations, which may be referred to other and even distant parts of the body.

The hypothesis, under consideration, affords us an explanation, more satisfactory than any other, of the paralytic state of the sphincter ani in brain disease, already referred to, as well as in that of the spinal cord. This muscle is certainly chiefly under the influence of he will. In ordinary cases of diseased brain where the lesion is coned to one side, the centre of volition is not sufficiently impaired to ffect its influence upon the sphincter. In graver lesions, however, lthough the will may still continue to exert its control upon one side f the body, it loses its power over the sphincter, which is not excitable by any stimulus. In disease of the spinal cord, there is paraysis of the sphincters if the lesion involve a sufficient portion of the ord's substance, in whatever region of the cord it may exist. Even when the lesion is situate high up in the neck, or in the dorsal region, eaving the lumbar portion perfectly whole, the sphincter will neverheless be paralyzed. In the former instances, the centre of volition n the cranium is diseased; in the latter, the defect consists in the lestruction of the communication of the brain with that portion of the ord in which the nerves of the sphincter muscle are implanted.

An examination of the action of the sphincter will show that the nus is kept closed ordinarily by the passive contraction of the muscle tself (see p. 180); but that its active contractions are mainly excited y voluntary influence, allowance being made for some slight action which may be produced by the stimulus of sudden distension, as in

other circular muscles. Now, as a stimulus to sentient nerves constitutes no necessary part of any of these actions, it is probable that the motor nerves of the sphincter have little or no connection with the sentient ones; and, consequently, that muscle is not excitable to contraction by a stimulus applied to a sentient surface. Hence, whenever the influence of the will upon the lumbar portion of the cord is suspended, this muscle ceases to act, whether a mental or a physical stimulus be exerted.

Dr. Hall indeed cites two experiments which imply that the action of the sphincter is dependent on the cord. In both, however, (one on a horse, the other on a turtle,) the observations were made immediately after division of the cord. By the division, the whole organ was thrown into an excited state, both above and below the section, and therefore manifested phenomena similar to those excited by volition. Indeed, we have seen the sphincter repeatedly contracting after division of the cord without the application of any new stimulus to it; and the dog continuing to raise and depress his tail as long as the irritation of the cord produced by the section has continued.

On the same principle, animals will exhibit movements of voluntary character for some time after decapitation. A bird thus treated will fly for some distance, and with considerable energy, and will flap its wings if the cut surface of the cord be irritated. A fly decapitated flies for some way immediately after the removal of the head; and Walckenaer observed a singular fact respecting the Cerceris ornata, a wasp which attacks a bee that inhabits holes: "at the moment that the insect was forcing its way into the hole of the bee, Walckenaer decapitated it; notwithstanding which, it continued its motions, and, when turned round, endeavoured to resume its position, and enter the hole."* The change in the vesicular matter of the ganglia necessary for the movements of the wasp in pursuit of its prey, had already been excited by a powerful stimulus of volition, which continued even after the removal of the centre from which it had emanated.

So similar is the change which a physical stimulus can excite in the gray matter to that produced by the influence of the will, that, as has been often remarked, the actions excited in decapitated animals present a striking resemblance to the ordinary voluntary movements. When a certain portion of the skin is irritated, the animal pushes against the offending substance, as if trying to remove or displace it. If the anus be irritated, both legs are excited to action. It may also be observed, that the same motions follow the same irritations of the skin. If, in a frog, the seat of irritation be on the right side, the corresponding hind-foot will be raised, as if to remove the irritating cause. The exact resemblance of these to voluntary movements seems to admit of being explained only on the supposition that the same fibres are employed in the execution of both.

It must be borne in mind, that, while this hypothesis rejects the class of sensori-volitional fibres which pass with the spinal nerves along the cord into the brain, it admits the existence of only three

* Quoted in Müller's Physiology, by Baly, vol. i. p. 787, 2d ed.

rders of fibres implanted in the various segments of the cord, viz., hose at once sensitive and excitor; those at once for voluntary and nvoluntary motion; and commissural fibres. Moreover, it is not ntended by this hypothesis to assume that the intervention of *sensa-ion* (*i. e.* the perception of an impression by the mind) is *necessary* or the production of those muscular actions which are excited by timulation of the surface. No more is affirmed than that the same timulus to the sensitive nerve which can and does excite a sensation, nay *simultaneously*, but *independently*, cause a change in the vesicular natter which shall stimulate the motor nerves; and that this change s of the same kind as that which the will may excite, and affects the ame motor nerves.

Lastly, this hypothesis involves the enunciation of a highly im-ortant proposition with reference to nervous centres. It is this: that ll the centres which are connected to the brain by commissural ibres, are thereby submitted to, and brought into connection with, he mind, to an extent proportionate to the number of connecting ibres, so that voluntary impulses act upon them as part and parcel of he centre of volition; and sensitive impressions, in affecting them, ffect the sensorium commune simultaneously.

In voluntary actions, then, it may be stated, that, while the brain s the part primarily affected, the mental impulse is at the same time lirected to that portion of the cord upon which the required action lepends.

In the development of sensation the stimulus affects the posterior orns of the gray matter of the cord, which, from its commissural onnection with the brain, is in reality a part of the sensorium. When the power of mental interference is removed, or kept under ontrol, physical actions develop themselves; being effected through he same nerves as those which volition influences, or which sensi-ive impressions affect. The latter are, in such instances, the excitors f the former, no doubt through the vesicular matter in which they re implanted. These actions become most manifest when the con-ection of the brain with the spinal cord has been severed; and they ccur in the most marked way in those situations where the cutaneous erves are so organized as readily to respond to the application of a timulus applied to the surface, or they become universal when the ord is in a state of general excitement.

The movements in locomotion and the maintenance of the various ttitudes, are effected through the ordinary channels of the physical nd volitional actions; and the posterior columns of the cord, by their nfluence on the vesicular matter of the segments in which the nerves re implanted, co-ordinate and harmonize the complicated muscular ctions of the limbs and the trunk under the control of that portion f the encephalon which probably is devoted to that purpose. This ower of co-ordination is probably mental, and intimately connected rith the muscular sense.

To conclude the discussion of the functions of the cord, we shall ere enumerate the physical nervous actions of which it is the centre, emarking, at the same time, that we continue to use the term spinal

cord in its ordinary sense, and that we reject the hypothesis of a *true spinal cord*, anatomically distinct from that which has to do with mental nervous actions.

We have already stated, that probably part of the muscular adjustments in locomotion are excited by the pressure against the soles of the feet. All involuntary movements of the muscles of the trunk or extremities, when excited by external stimuli, have their centre in the spinal cord. The sudden application of cold to the surface of the trunk or extremities frequently excites respiratory movements. This may be attributed to cutaneous nerves affecting the gray matter of the cord, and through this the intercostal and phrenic nerves implanted in it.

Certain conditions of the generative organs are dependent on the spinal cord; but they are developed only in a polar state of that organ, usually present under sexual excitement. Erection of the penis is evidently dependent on the cord in this way. In a state of irritation of the cord, such as may be caused by traumatic injury, erection or semi-erection is frequently present. In paraplegia there is frequently an absence of the power. The excited state of the Fallopian tubes in the female is attributable to the same cause. The action of the uterus in parturition, of the bladder and rectum when distended, is partly due to the stimulus of distension on the muscular coats, and partly to the physical power of the cord excited by the sensitive nerves of those organs.

The nervous actions which accompany the nutritive functions are of the physical kind, although not altogether removed from the influence of volition and emotion, and have their centre in the spinal cord. Thus, the heart is very liable to be influenced by the spinal cord, and, no doubt, the blood-vessels are similarly related to it; and, through their influence upon the distribution of blood to the various textures, it is plain that the state of the spinal cord, or of parts of it, may readily affect the molecular changes in which nutrition and secretion intrinsically consist. This subject will be further discussed when we come to consider the functions in question.

It has been supposed, that the tone of the muscular system is maintained by the spinal cord. If by *tone* be meant what we have described as *passive contraction*, we can only remark, that the phenomena which characterize that state are just as obvious in muscles taken from animals recently deprived of the spinal cord as in others; and that the analogous state, rigor mortis, comes on as distinctly when the spinal cord and brain have been removed, as if they were untouched. Healthy nutrition, in our opinion, supplies all the conditions necessary for the maintenance of the tone or the passive contraction; nor is the spinal cord (although itself healthy) able to preserve the tense condition of the muscles, if they are not well nourished. The removal of the spinal cord, indeed, immediately produces a flaccid state of the muscles of the limbs; but this is owing to the immediate cessation of the slight degree of active contraction necessary to maintain a certain posture. A decapitated frog will continue in the sitting posture through the influence of the spinal

ord; but, immediately this organ is removed, the limbs fall apart, rom the loss of the controlling and co-ordinating influence of the ervous centres. But careful examination will show, that in these mbs the molecular phenomena which characterize passive contracion continue. It must be remarked, however, that muscles separated rom their proper nervous connection soon suffer in their nutrition, rom the want of that amount of exercise which is necessary for it. For this important observation we are indebted to Professor John Reid, who likewise called attention to the confirmatory fact, that, in hose palsies with which there is combined more or less irritation of he nervous centre, the muscles do not suffer in their nutrition, in onsequence of the exercise they undergo in the startings so frequently xcited in them by the central irritation.

After these remarks, it is scarcely necessary to add, that we must nter our protest against the doctrine which assigns the spinal cord as he source of muscular irritability. This doctrine, indeed, has but lender support either in reason or experience. It is contrary to all nalogy to assign to one tissue the power of conferring vital properties n another. If bone, tendon, and cartilage have their distinctive properties, they possess them in virtue of some peculiarity inherent in heir mode of nutrition, and do not derive them from any other texture. And, surely, it is too much to suppose that a tissue, like muscle, so omplex in its chemical constitution, and so exquisitely organized for he development of its proper force, should be dependent on the ervous system, or a portion of it, for its contractile power! Our wn experience is quite opposed to the statement of Dr. Hall, that, n cases of palsy dependent on cerebral lesion, the muscles of the ffected limbs acquire an increased irritability, from the cord, which e supposes to be the source of irritability, remaining intact, while he influence of the exhauster of irritability (the brain) is removed. n all our experiments, which have been numerous, we have found he palsied muscles less excitable by the galvanic stimulus than those f the sound side, and the difference has been more manifest the onger the period since the paralytic seizure. Exceptions to this tatement, however, are found in those cases in which the paralysis as been accompanied with cerebral irritation sufficient to keep up a tate of more or less *active* contraction of the affected muscles.*

Functions of the medulla oblongata, mesocephale, corpora striata, nd optic thalami.—Although the anatomist may find it convenient o describe these parts each by itself, it is impossible, in the consileration of their functions, to separate them completely, they are so losely connected with each other, and the functions of one part are o readily affected by any change in those of the other. Thus, the livary columns, which form the central and most essential part of he medulla oblongata, extend upwards through the mesocephale to he optic thalami; and the anterior pyramids form an intimate conection not only with the vesicular matter of the mesocephale, but,

* See also Dr. Pereira's experiments, Mat. Med., vol. ii. p. 1301.

to a great extent, with that of the corpora striata. All these parts taken together, with the quadrigeminal tubercles, will be found to be the centre of the principal mental nervous actions, and of certain physical actions which are very essential to the integrity of the economy.

The office of the nerves which arise from the segment of the encephalon throws light upon its function. These nerves are partly destined for respiration, partly for deglutition, and partly also for acts of volition and sensation.

Destruction of the medulla oblongata is followed by the immediate cessation of the phenomena of respiration; and this takes place whether it be simply divided, or completely removed. When an animal is pithed, he falls down apparently senseless, and exhibiting only such convulsive movements as may be due to the irritation of the medulla by the section, or such reflex actions as may be excited by the application of a stimulus to some part of the trunk.

If, in an animal which breathes without a diaphragm, as in a bird or reptile, the spinal cord be gradually removed in successive portions, proceeding from below, up to within a short distance of the medulla oblongata, loss of motor and sensitive power takes place successively in the segments of the body with which the removed portions of the cord were connected. But the animal still retains its power of perceiving impressions made on those parts of the body which preserve their nervous connection with the medulla oblongata, and continues to exercise voluntary control over the movements of those parts. The movements of respiration go on, and deglutition is performed. The higher senses are unimpaired. (*Flourens*, p. 179.)

These phenomena are sometimes observed in man—in such cases as that alluded to in a former page; where, from injury to the spinal cord in the neck, below the origin of the phrenic nerve, the patient appears as a living head with a dead trunk. The sensibility and motor power of the head are perfect; respiration goes on partially, and deglutition can be readily performed. The senses and the intellectual faculties remain for a time unimpaired.

Irritation of any part of the medulla oblongata excites convulsive movements in muscular parts which receive nerves from it, and, through the spinal cord, in the muscles of the trunk. Spasm of the glottis, difficulty of deglutition, irregular acts of breathing, result from irritation of the medulla oblongata; and, if the excitement be propagated to the cord, convulsions will become more or less general.

If a lesion affect one-half of the medulla oblongata, does it produce convulsions or paralysis on the opposite side of the body? This question may be certainly answered in the affirmative, when the seat of the lesion is in the continuations of the columns of the medulla oblongata above the posterior margin of the pons. It is not so easily solved, however, when the disease is situate below the pons. The results of experiment on this subject are contradictory, owing probably to the extreme difficulty of limiting the injury inflicted to a portion of the medulla on one side; and those of Flourens are of no value for

the decision of this question, as it appears that he injured chiefly the restiform bodies. Anatomy suggests, that a lesion limited to either anterior pyramid would affect the *opposite* side of the trunk, for it is known that such an effect follows disease of the continuation of it in the mesocephale or crus cerebri; and that lesion limited to the posterior half of the medulla on either side would affect the *same* side of the body, no decussation existing between the fibres of opposite restiform or posterior pyramidal bodies. The irritating or depressing influence of the lesion would probably be extended to the spinal gray matter of the same side.

That the medulla oblongata is the channel through which the operations of the brain are associated in voluntary actions with the spinal cord, is shown by the fact that paralysis of all the muscles of the trunk follows the separation of the latter organ from the former. It seems not improbable that the centre of volition is connected with one or both of the gangliform bodies (corpora striata and optic thalami) in which the columns of the medulla oblongata terminate above. When the cerebral hemispheres have been removed, as in Flourens' and in Magendie's experiments, the bird is thrown into a deep sleep, a state of stupefaction, and insensibility to surrounding objects. But he can maintain his attitude—stand—walk, when first propelled—fly, if thrown into the air. This continuance of the locomotive power implies some degree at least of mental or volitional effort. All the animal's movements have much of the appearance of the exercise of will, although, doubtless, many of them are in a great degree excited by physical stimuli. Hence there seems reason to believe that the will exerts a primary influence upon either or both of these gangliform bodies, more vigorous when aided and guided by the power of the cerebral hemispheres. The frequent paralysis of motion apart from sensation when the upward continuations of the pyramidal fibres in the corpora striata are diseased, renders it extremely probable that these fibres are the media of connection between the brain and cord in voluntary actions.

The medulla oblongata is not less the medium for the transmission of sensitive impressions from all the regions of the head, trunk, and extremities; and from its olivary columns at their upper and posterior part being, as it were, the concourse of all the nerves of pure sense, it seems fair to assign these parts as the prime seat of those central impressions which are necessary for sensation. The reception of these impressions by the cerebral hemispheres is the stage immediately associated with mental perception. True sensation, therefore, cannot take place without cerebral hemispheres. In a sensation excited in parts supplied by spinal nerves, the first central change is probably in the posterior horn of the vesicular matter of the cord; and the olivary column of the medulla oblongata is simultaneously affected, from its connection with the cord. The change in this latter part is then propagated to the cerebral hemispheres.

Thus much is suggested by anatomy, as regards the mechanism of sensitive impressions. Experiment affords us no aid in this intricate

and difficult subject; neither does pathological anatomy: for the parts are so closely associated with each other, that any morbid state of one readily involves the others, so that it is almost impossible to find a morbid state of the parts devoted to sensation, apart from an affection of those more immediately concerned in motion.

The function of the restiform bodies is probably associated with that of the hemispheres of the cerebellum, and of the posterior columns of the spinal cord.

The experiments of Le Gallois and Flourens render it certain that the medulla oblongata is the centre of respiratory movements. The latter physiologist assigns as the "primum movens" of these acts all that portion of the medulla which extends from the filaments of origin of the vagus nerve to the tubercula quadrigemina, the former only inclusive. Destruction of this portion, in whole or in part, invariably impairs or destroys the respiratory actions, and a morbid state of it gives rise to irregular or excited movements of respiration. Sighing, yawning, coughing, are probably connected with excitation of this centre, either direct, or propagated to it from some sentient surface.

This portion of the encephalon is also the centre of action in the movements of deglutition, through fibres of the glosso-pharyngeal and vagi nerves. A morbid state of it occasions difficulty, or even paralysis, of deglutition. Animals deprived of the cerebral hemispheres and cerebellum will preserve the power of swallowing food introduced within the grasp of the fauces, so long as the medulla oblongata continues uninjured. In fœtuses born without cerebral hemispheres, those actions are present which depend on the spinal cord and medulla oblongata; all the movements of respiration and deglutition are performed as well as in the perfect fœtus. Mr. Grainger's experiments show that puppies deprived of the hemispheres of the brain can perform the movements of suction with considerable vigour, when the finger is introduced into the mouth, (*loc. cit.*, pp. 80–1,) and the remarkable fact of the adhesion of the fœtus of the kangaroo to the nipple within the pouch, no less than its respiratory movements, must, as this author remarks, be regarded as a most interesting display of the physical power of the medulla oblongata, while the rest of the brain is as yet undeveloped.

The actions of respiration and deglutition are, to a great extent, of the physical kind, being excited by impressions propagated from the periphery. In those of respiration, the ordinary exciting cause is probably, as Dr. Hall supposes, due to the chemical changes in the respired air which are effected in the lungs. These movements may be, to a certain extent, controlled by the will; but every one is conscious, from his own sensations, that after a time the physical stimulus is capable of conquering the restraining influence of the mind; a striking example of a mental stimulus giving way to a physical one; and illustrative, as we think, of the doctrine that the same fibres are affected by both stimuli. The excitation of the medulla oblongata in respiration does not, however, depend solely upon the pulmonary

ves. Those of the skin are capable of exciting it, either directly the fifth pair, or through the spinal cord, as is proved by the inrations which are instantly excited by suddenly dashing cold water the face or trunk.

In deglutition, the exciting cause is the stimulus of contact applied the mucous membrane of the fauces. So highly sensitive is the cous membrane in this situation, that the slightest touch of it with eather is sufficient to produce contraction of the muscles of degluon, which the will is scarcely able to control. Without this stimu-, it is doubtful whether these muscles would obey the will alone; d it seems probable that this part of the act of deglutition must be garded as one of those actions referred to at a former page, which quire a double stimulus, both mental and physical, for their full rformance. (See p. 296.)

The medulla oblongata and its continuations in the mesocephale pear to be the centre of those actions which are influenced by otion. The common excitement of movements of deglutition or piration, or of sensations referred to the throat, under the influence emotion, evidently points to this part of the cerebro-spinal centre being very prone to obey such impulses; and as the nerves of pure se, especially the optic and auditory, are very commonly the annels of sensitive impressions well calculated to arouse the feel-gs, it seems highly probable that the centre of such actions should contiguous to the origin of these nerves. We would assign this ice to that region of the mesocephale which is in the vicinity of the adrigeminal tubercles. It is not a little remarkable that the nerves hich arise from this and the neighbouring parts are very readily luenced by emotions. Thus, the third and fourth pairs of nerves gulate the principal movements of the eyeballs, those especially iich most quickly betray emotional excitement; and the portio dura the seventh pair, the motor nerve of the face, is the medium ough which changes of the countenance are effected. It may be ded, that the centre of emotional actions ought to be so situated it it could readily communicate with the centres of all the volunty actions of the body, and with the immediate seat of the inlectual operations, as well as with the nerves of pure sense; and part possesses these relations so completely as that to which we er.

In those diseases which mental emotion is apt to give rise to, many the symptoms are referable to affection of the medulla oblongata. hysteria, the globus, or peculiar sense of suffocation or constriction out the fauces; in chorea, the difficulty of deglutition, the peculiar vement of the tongue, the excited state of the countenance, the ficulty of articulation, may be attributed to the exalted polarity of centre of emotional actions. In hydrophobia this part is probably rays affected, and frequently so in tetanus.

Certain gangliform bodies are connected with the upward connations of the medulla oblongata, both in the brain and in the socephale, which doubtless have proper functions. These are the pora striata, optic thalami, and quadrigeminal bodies.

Corpora striata.—The anatomy of the corpora striata and optic thalami, while it denotes a very intimate union between them, also shows so manifest a difference in their structural characters, that it cannot be doubted that they perform essentially different functions. In the corpora striata the fibrous matter is arranged in distinct fasciculi of very different size, many, if not all of which, form a special connection with its vesicular matter. In the optic thalami, on the other hand, the fibrous matter forms a very intricate interlacement, which is equally complicated at every part. Innumerable fibres pass from one to the other, and both are connected to the hemispheres by extensive radiations of fibrous matter. The corpora striata, however, are connected chiefly, if not solely, with the inferior fibrous layer of each crus cerebri; whilst the optic thalami are continuous with the superior part of each crus, which is situate above the locus niger.

It will be observed, then, that while these bodies possess, as a principal character in common, their extensive connection with the cerebral hemispheres, or, in other words, with the convoluted surface of the brain, they are, in the most marked way, connected inferiorly with separate and distinct portions of the medulla oblongata; the corpora striata with the inferior fibrous planes of the crura cerebri and their continuations, the anterior pyramids; and the optic thalami with the olivary columns, the central and probably fundamental portions of the medulla oblongata. And this anatomical fact must be taken as an additional proof of their possessing separate functions.

Now, it may be inferred, from their connections with nerves chiefly of a sensitive kind, that the olivary columns, and the optic thalami, which are continuous with them, are chiefly concerned in the reception of sensitive impressions, which may principally have reference merely to informing the mind (so to speak), or partly to the excitation of motion, as in deglutition, respiration, &c. The posterior horns of the gray matter of the cord, either by their direct continuity with the olivary columns, or their union with them through commissural fibres, become part and parcel of a great centre of sensation, whether for mental or physical actions.

The pyramidal bodies evidently connect the gray matter of the cord (its anterior horns?) with the corpora striata; and not only these, but also the intervening masses of vesicular matter, such as the locus niger, and the vesicular matter of the pons, and of the olivary columns; and, supposing the corpora striata to be centres of volition in intimate connection with the convoluted surface of the brain by their numerous radiations, all these several parts are linked together for the common purposes of volition, and constitute a great centre of voluntary actions, amenable to the influence of the will at every point.

It has been pretty generally admitted by anatomists, that both the corpora striata and the anterior pyramids are concerned in voluntary movements. The motor tracts of Bell were regarded by that physiologist as passing upwards from the anterior columns of the cord to the corpora striata, and, after traversing those bodies, as diverging into the fibrous matter of the hemispheres; and the fact of the origin

of certain motor nerves, in connection with those fibres, was considered to be very favourable to this view. The decussation of the pyramids, likewise, so illustrative of the cross influence of the brain in lesions sufficient to produce paralysis, has been looked upon as an additional indication of the motor influence of these parts.

The invariable occurrence of paralysis as the result of lesion, even of slight amount, in the corpora striata, must be regarded as a fact of strong import in reference to the motor functions of these bodies. Nor is this fact at all incompatible with the statements made by all experimenters, that simple section of the corpus striatum does not occasion either marked paralysis or convulsion; and that in cutting away the different segments of the brain, beginning with the hemispheres, convulsions are not excited until the region of the mesocephale is involved. The influence of the corpora striata is not upon the nerves *directly*, but upon the segments of the medulla oblongata or of the spinal cord, and, through them, upon the nerves which arise from them. Were the nerve-fibres continued up into the corpora striata, according to an opinion which has been long prevalent, there would be no good reason for supposing that they should lose in the brain that excitability to physical stimuli which they are known to possess in the spinal cord, and at their peripheral distribution.

The latest experiments, which are those of Longet and Lafargue, agree in the following result, which is not at variance with that obtained by Flourens. The animals remain immovable after the removal of the corpora striata, whether those bodies have been removed alone or in conjunction with the hemispheres; nor do they show any disposition to move, unless strongly excited by some external stimulus. None of these observers had noticed the irresistible tendency to rapid propulsion, which was described by Magendie. Removal of the corpus striatum of one side caused weakness of the opposite side.

In order to form a due estimate of these experiments, it must be borne in mind, that the effect of simple excision of either corpus striatum would be very different from those of diseases of it. The depressing effects of the latter would be absent, at least, until some alteration in the process of nutrition had been set up in the mutilated parts. Simple excision of the centre of volition, and inflammatory diseases of its substance, or an apoplectic clot, must produce essentially different effects;—the one simply cuts off the influence of the will, the other affects the vital action, and, consequently, the vital power of the centre, and of the commissural fibres connected with it.

Judging from structure only, it might be conjectured that the *locus niger*, that remarkable mass of vesicular matter which separates the anterior and posterior planes of each crus cerebri, exerts a motor influence. It resembles in structure the anterior horns of the gray matter of the cord, and contains numerous large caudate vesicles with very abundant pigment.

Optic thalami.—The same line of argument which leads us to view the corpora striata as the more essential parts of the nervous

apparatus which control direct voluntary movements, suggests that the optic thalami may be viewed as the principal foci of sensibility, without which the mind could not perceive the physical change resulting from a sensitive impression.

The principal anatomical fact which favours this conclusion, is the connection of all the nerves of pure sense, more or less directly, with the optic thalami or with the olivary columns. The olfactory processes, which apparently have no connection with them, form, no doubt, through the fornix, such a union with them, as readily to bring them within the influence of the olfactory nerves.

According to this sense of its office, we must regard the optic thalami as the upper and chief portions of an extended centre, of which the lower part is formed by the olivary columns, which we have already referred to as taking part in the mechanism of sensation. The continuity of the olivary columns with the optic thalami justifies this view: nor is it invalidated by the fact, that some of the nerves which arise from the medulla oblongata are motor in function; for Stilling's researches render it probable that these fibres have their origin in special accumulations of vesicular matter, which contain caudate vesicles of the same kind as those found in the anterior horns of the gray matter of the cord. (See fig. 70.)

The results which experiments have yielded, add little that is positive to our knowledge of the functions of these bodies. Flourens found that neither pricking nor cutting away the optic thalami by successive slices, occasioned any muscular agitation, nor did it even induce contraction of the pupils. Longet found that removal of one optic thalamus in the rabbit was followed by paralysis on the opposite side of the body. It appears, however, that this was done after the removal of the hemisphere and corpus striatum, whereby the experiment was so complicated as to invalidate any conclusion that might be drawn from it respecting the function of the thalamus. Indeed, vivisections upon so complex an organ as the brain are ill calculated to lead to useful or satisfactory results; but we do not hesitate to quote such as have been made, from the imperfect negative information which they afford.

Nothing definitive respecting the proper office of the thalami can be obtained from pathological anatomy. Extensive disease of these bodies is attended with the same phenomena during life, as lesion of similar kind in the corpora striata. Hemiplegic paralysis accompanies both; nor does it appear that sensation is impaired when the thalamus is diseased, more than when the corpus striatum is affected.

We see nothing in the phenomena which attend morbid states of the thalami, to oppose the conclusion which their anatomical relations indicate, namely, that they form a principal part of the centre of sensation. The intimate connection between the striated bodies and the thalami, sufficiently explains the paralysis of motion which follows disease of the latter; whilst, as the thalami do not constitute the *whole centre* of sensation, but only a part, it cannot be expected that lesion of this part would destroy sensation, so long as the remainder of the centre on the same side, as well as that of the oppo-

te side, retain their integrity. Complete paralysis of sensation on se side is very rare in diseased brain: a slight impairment of it freuently exists in the early periods of cerebral lesion, apparently as a effect of shock; for it quickly subsides, although the motor power ay never return.

According to the views above expressed, the corpora striata and ptic thalami bear to each other a relation analogous to that of the nterior to the posterior horn of the spinal gray matter. The corpora triata and anterior horns are centres of motion; the optic thalami nd posterior horns centres of sensation. The anterior pyramids conect the former; the olivary columns, and perhaps some fibres of the terior pyramids, the latter. The olivary columns, however, are in reat part continuations of the thalami on the one hand, and of the ray matter of the cord on the other: and contain abundance of veicular matter, in which nerves are implanted.

And it must be admitted that the intimate connection of sensation nd motion, whereby sensation becomes a frequent excitor of motion, —and voluntary motion is always, in a state of health, attended with sensation,—would *à priori* lead us to look for the respective centres f these two great faculties, not only in juxtaposition, but in union t least as intimate as that which exists between the corpus striatum nd optic thalamus, or between the anterior and the posterior horns of e spinal gray matter.

Saucerotte, Foville, Pinal Grandchamps, and others, advanced the inion that the corpora striata and the fibrous substance of the anrior lobes of the brain had a special influence upon the motions of e lower extremities, and that the optic thalami and the fibrous subance of the middle and posterior part of the brain presided over the ovements of the upper extremities. We find, however, but little favour this theory either in the results of experiments, in pathogical observation, or the anatomy of the parts. Longet states, that, his experiments upon the optic thalami, the paralysis affected ually the anterior and the posterior extremities. Andral analyzed venty-five cases of cerebral lesion limited to the corpus striatum or tic thalamus. In twenty-three of these cases, the paralysis was onfined to the upper extremity: of these, *eleven* were affected with sion of the corpus striatum or of the anterior lobe; *ten* with lesion the posterior lobe, or of the optic thalamus; and *two* with lesion the middle lobe.* Hence it is plain that a diseased state of the rpus striatum is as apt to induce paralysis of the upper extremity, lesion of the thalamus; and we are forced to conclude, that pathogical anatomy is not competent to decide the question. Lastly, the atomy of these two bodies renders it highly improbable that they rform a function so similar, as that of directing the movements of rticular limbs. The great size of the optic thalamus, its multitude fibrous radiations, its extensive connections both in the medulla longata and in the hemispheres by means of commissural fibres,

* Clin. Med. t. v.

the marked difference of its structure from that of the corpus striatum, its connection more with the posterior horns of the spinal gray matter than with the anterior ones, and its intimate relation to nerves of sensation, are, in our judgment, sufficient anatomical facts to warrant the opinion that the thalami must perform a function which, although it may be subservient to, or associated with, that of the striated bodies, is yet entirely dissimilar in kind.

It has been supposed that the corpora striata are special centres or ganglia to the olfactory nerves, and to the sense of smell. But such a supposition is altogether superfluous, inasmuch as a very distinct and obvious centre to these nerves exists in the olfactory process or lobe, miscalled *nerve* by descriptive anatomists. The small olfactory nerves are implanted in the anterior extremity or bulb of this process, which is provided with all the structural characters of a nervous centre, and contains a ventricle. This lobe, moreover, is always developed in the direct ratio of the size and number of the olfactory nerves, and of the development of the sense of smell; and in the Cetacea, a class in which the olfactory nerves and process either do not exist at all, or are so imperfectly developed as to have escaped the notice of some of the ablest anatomists, the corpora striata are of good size proportionally to that of the entire brain.

Corpora quadrigemina.—The marked connection of these gangliform bodies with the optic nerves plainly indicates that they bear some special relation to those nerves, and to the sense of vision; and this indication becomes more certain when we learn, from comparative anatomy, that in all vertebrate tribes in which the encephalon is developed, special lobes exist, bearing a similar relation to the optic nerves (pp. 249–50). When the optic nerves are large, these lobes are large; and in the pleuronecta, in which the eyes are of unequal size, Gottsche states that the optic lobes are unequal. Still, as Serres has remarked, the quadrigeminal tubercles probably perform some other office besides that which refers to vision; inasmuch as the absence, or extremely diminutive size, of the optic nerves in some animals (the mole, for instance), does not materially affect that of these bodies. (*Cyclop. Anat.*, art. *Optic nerves.*)

Flourens found that destruction of either of these tubercles on one side was followed by loss of sight of the opposite side, and consequently that the removal of both deprived the animal altogether of the power of vision, but did not affect its locomotive or intellectual powers, nor its sensibility, except to light. In these experiments the action of the iris was not impaired if the tubercles were only partially removed; as long as any portion of the roots of the optic nerves remained uninjured, the iris continued to respond to the stimulus of light, but the total removal of the tubercles paralyzed the irides. If the lobes of the brain and cerebellum were removed, leaving the tubercles untouched, the irides would continue to contract. These experiments leave no room to doubt that the optic tubercles are the encephalic recipients of the impressions necessary to vision, which doubtless are simultaneously felt by means of the optic thalami; and

hey are the centres of those movements of the iris which con-
e largely not only to protect the retina, but likewise to increase
erfection of vision. The optic nerve is at once the nerve of
1, and the excitor of motor impulses which are conveyed to the
y the third nerve, which takes its origin very near to the optic
cles. It is interesting to add, that irritation of an optic tubercle
ie side causes contraction of both irides:—this is quite in accord-
with the well-established fact, that, if light be admitted to one
o as to cause contraction of its pupil, the other pupil will con-
at the same time. So simultaneous is the action of the two
es; so rapid must be the transmission of the stimulus from one
o the other.

hen the injuries inflicted on these tubercles were deep, more or
general convulsive movements were produced; if one tubercle
injured, the opposite side only was so affected. These con-
ns were due to the lesion of the central parts of the medulla
gata, with which the optic tubercles are intimately connected.
arkable vertiginous movement was likewise caused, the animal
g to the side from which the tubercle had been removed. It
ot appear that this rotation could be attributed to any special
ice of the medulla oblongata, but rather to a state of vertigo
d by the partial destruction of vision; for Flourens found that
ne effects could be produced in pigeons by blindfolding one
The movements, however, were not so rapid, nor did they
ue so long. And Longet saw the same movements in pigeons
ch he had evacuated the humours of one eye.*

ay be remarked, that deep injuries to the quadrigeminal tuber-
e very likely to affect the only commissural connection between
rebrum and cerebellum (*processus cerebelli ad testes*), the in-
of which must doubtless be essentially necessary to ensure
ny of action between these two great nervous centres.

re are many instances on record in which blindness was coin-
with pathological alteration of structure in one or both quadri-
il tubercles. In some of the cases where the lesion extended
s seated beneath the tubercles, disturbed movements were ob-
, as in the experiments above related.

are ignorant of the object of the extensive connections of the
racts with the tuber cinereum, the crura cerebri, and the cor-
eniculata; but these points are highly worthy of future inquiry,
lly with reference to the office of these last-named bodies,
is at present involved in much obscurity. Many of the fibres
optic tracts are undoubtedly commissural between the corre-
ng points of opposite sides, and exist when those which form
ic nerves are deficient.

see, then, in the quadrigeminal tubercles, centres, which,
er other functions they may perform, have a sufficiently ob-
relation to the optic nerves, the eye, and the sense of vision.

rens' experiments have been amply confirmed by those of Hertwig and

This is clearly indicated by anatomical facts, by the results of experiment, and by the phenomena of disease. These bodies may, therefore, be justly reckoned as special ganglia of vision; and we are led to seek for similar centres in connection with the other senses. The olfactory processes seem very probably to perform a similar office in reference to the sense of smell. Their structure, their relation to the olfactory nerves, and their direct proportion of bulk to that of these nerves, and to the development of the olfactory apparatus, place this question beyond all doubt. It is not so easy to determine the special ganglia of hearing; but the olivary bodies, or the small lobules connected with the crura cerebelli, called by Reil *the flocks*, may be referred to as bearing a sufficient close anatomical relation to the auditory nerve to justify our regarding either of them as well calculated to perform this function. And, with respect o touch, the ganglia on the posterior roots of the spinal and the fifth nerves may perhaps be considered in the same light; for this sense being diffused so universally, in various degrees, over the whole surface of the body, and being seated in a great number of different nerves, would need ganglia in connection with all those nerves which are adapted to the reception of tactile impressions. The analogous sense of taste has its ganglia in those of the glosso-pharyngeal and the fifth.*

The upper and posterior part of the mesocephale has already been referred to, as being most probably that part of the brain which is most directly influenced by emotional excitement. Dr. Carpenter appears to localize the seat of emotional influence more specially in the corpora quadrigemina, and refers to certain fibres, which he considers terminate in those bodies, as channels of emotional impulses. Although we cannot agree with this able writer in this limitation of the centre of emotion (so to speak), nor in the existence of a distinct series of fibres for emotional acts, we think the arguments he advances are most applicable to that view which refers the influence of emotion to the gray matter of this entire region, which s brought into connection with the spinal cord by the fibres of the anterior pyramids, as well as probably through the continuity of the olivary columns and the posterior horns of the spinal gray matter.

Every one has experienced in his own person how the emotions of the mind, whether excited by a passing thought, or through the external senses, may occasion not only involuntary movements, but subjective sensations. The thrill which is felt throughout the entire frame when a feeling of horror or of joy is excited, or the involuntary shudder which the idea of imminent danger or of some serious hazard gives rise to, are phenomena of sensation and motion excited by emotion. The nerves which take their origin from the medulla

* It may be urged against this conjecture respecting the functions of the ganglia of the spinal nerves and the fifth, that the analogy between these bodies and the quadrigeminal tubercles is incomplete, inasmuch as the optic nerves are probably *implanted* in the latter, but the nerves of touch merely *pass through* the former. But, in truth, we know so little of the positive relation of the nerves in question to the ganglia, that no argument, either for or against the above view, can rest upon such imperfect information.

oblongata, mesocephale, or crura cerebri, are especially apt to be affected by emotions. The choking sensation which accompanies grief is entirely referable to the pharyngeal branches of the glosso-pharyngeal and vagi nerves, which come from the olivary columns. The flow of tears which the sudden occurrence of joy or sorrow is apt to induce may be attributed to the influence of the fifth nerve, which is also implanted in the olivary columns, upon the lachrymal gland; or of the fourth nerve, which anastomoses with the lachrymal branch of the fifth. The more violent expressions of grief, sobbing, crying, denote an excited state of the whole centre of emotion, involving all the nerves which have connection with it, the portio dura, the fifth, the vagus, and glosso-pharyngeal; and even the respiratory nerves, which take their origin from the spinal cord, as the phrenic, spinal accessory, &c. And laughter, "holding both his sides," causes an analogous excitation of the same parts of the central organ and of the same nerves. The very different effect produced by the excitement of the same parts must be attributed to the different nature of the mental stimulus.

As the passing thought—the change wrought during the exercise of the intellect—may excite the centre of emotion, so this latter may exert its influence upon the general tenor of the mind, and give to all our thoughts the tinge of mirth or sadness, of hope or despondency, as one or the other may prevail. We say of one man, that he is constitutionally morose; of a second, that he is naturally gay and mirthful; and of a third, that he is a nervous man, and that he is not likely to be otherwise. One man allows his feelings to hurry him on to actions which his intellect condemns; whilst another has no difficulty in keeping all his feelings in entire subjection to his judgment. "Of two individuals with differently constituted minds," remarks Dr. Carpenter, "one shall judge of everything through the medium of a gloomy morose temper, which, like a darkened glass, represents to his judgment the whole world in league to injure him; and all his determinations, being based upon this erroneous view, exhibit the indications of it in his actions, which are themselves, nevertheless, of an entirely voluntary character. On the other hand, a person of a cheerful, benevolent disposition, looks at the world around as through a Claude-Lorraine glass, seeing everything in its brightest and sunniest aspect, and, with intellectual faculties precisely similar to those of the former individual, he will come to opposite conclusions; because the materials which form the basis of his judgment are submitted to it in a very different form." Such examples abundantly illustrate the important share which the emotions take in the formation and development of character, and how all things presented to the mind through the senses may take their hue from the prevailing state of the feelings. If a certain part of the brain be associated with emotion, it is plain that that part must be in intimate connection with the seat of change in the operations of the intellect, in order that each may affect the other; that the former may prompt the latter, or the latter excite or hold in check the former. And this association of the emotions with a certain portion

of the brain explains the influence of natural temperament, and of varying states of the physical health, upon the moral and intellectual condition of individuals. We may gather from it how necessary it is to a well-regulated mind that we should attend not to mental culture only, but to the vigour and health of the body also; that to ensure the full development of the *mens sana* we must secure the possession of the *corpus sanum*.

Certain diseases are evidently associated with disturbed or excited states of emotion. In such cases, the nerves most affected are those connected with the mesocephale and medulla oblongata, denoting an excited state of those portions of the encephalon. Of these diseases the most remarkable are *hysteria* and *chorea*; both of which may be induced either by a cause acting primarily upon the mind, or by functional disturbance of the body, as deranged assimilation, in persons of a certain character of constitution. In hysteria, the globus, the tendency to cry or laugh, the disturbed breathing, the variously deranged state of the respiratory acts, all denote affection of most, if not all, the nerves coming from those segments. In chorea the frequent movements of the face and eyes, the peculiar and very characteristic mode of protruding the tongue, the impaired power of articulation, are dependent on an altered state of that part in which the portio dura of the seventh pair, the third, fourth, and sixth, and the ninth nerves are implanted. In both diseases the principal central disturbance is in the mesocephale; and that may be caused either by the direct influence of the mind upon it, or by the propagation of a state of irritation to it from some part of the periphery. Chorea, even of the most violent and general kind, is very commonly produced by sudden fright; and it is well known how frequently mental anxiety or excitement develops the paroxysm of hysteria.

There is no part of the cerebro-spinal centre which appears to exercise such extensive sway over the movements and sensations of the body as this portion, the mesocephale, which we regard as the centre of emotional actions. Its influence extends upwards to the cerebral convolutions—backwards to the cerebellum—downwards to all the nerves of sensation and motion. Through its connection with the posterior horns of the spinal gray matter, it can excite the sensitive as well as the motor nerves of the trunk. Hence it is not to be wondered at that a highly disturbed state of this centre is capable of deranging all the sensitive as well as motor phenomena of the body, and even the intellect. Hence we may explain the extraordinary movements in hydrophobia and general chorea, in both of which diseases this part of the nervous centre is doubtless affected. It has often been remarked how much more powerful are the voluntary actions when prompted by some strong emotion, than when excited only by an effort of the will. Rage, or despair, is able to magnify the power of the muscles to an incalculable degree. This may be due to the increased stimulus derived from the influence of the centre of emotion being conjoined with that of the centre of volition.

The intimate connection of the olivary columns with the gray

matter of the cord, and through that with all the roots of the spinal nerves, illustrates the power of emotional changes upon the organic processes. How often does the state of the feelings influence the quantity and quality of the secretions, no doubt through the power of the nerves over the capillary circulation! Blushing is produced through an affection of the mind, acting primarily on the centre of emotion, and through it on the nerves, which are distributed to the capillary vessels of the skin of the face.

The sexual passion must be ranked among the mental emotions. Like them, it may be excited and ministered to by a certain line of thought, or by particular physical states of the sexual organs. It seems, therefore, more correct to refer this emotion to the common centre of all, than to a special organ—according to Gall's theory; and it may be remarked, that great development of this part of the brain is just as likely to produce great width of cranium in the occipital region as a large cerebellum.

Of the functions of the cerebellum.—All anatomists are agreed in admitting, in the whole vertebrate series, (the amphioxus excepted,) the existence of a portion of the encephalon which is analogous to the cerebellum. This extensive existence of such an organ indicates its great physiological importance, as a special element of the encephalon. The cerebellum exhibits much difference both as regards size and complexity of structure in the different classes; and although, upon the whole, it increases in its development in the same ratio as the hemispheric lobes, it exhibits no constant relation of size to those parts.

The large size and complicated structure of this organ in the higher vertebrate animals, and its distinctness from the other parts of the brain,—for its commissural connections are not extensive,—have excited the interest and curiosity of speculative physiologists; and, accordingly, we find no part respecting which a greater variety of hypotheses have been suggested, most of them being entirely devoid of foundation. The experiments of Flourens have, however, thrown more light on this subject than any previous observations; and his hypothesis appears to us nearer the truth than any which has been proposed. We shall content ourselves with examining this theory, as well as that of Gall, which assigns the cerebellum as the organ of the sexual instinct.

The facility with which the cerebellum may be removed or injured, especially in birds, without involving the other segments of the brain, renders it a much more favourable object for direct experiment than them. A skilful operator may remove the greater part or the whole of the cerebellum without inflicting any injury on the hemispheres or other parts.

Flourens removed the cerebellum from pigeons by successive slices. During the removal of the superficial layers there appeared only a slight feebleness and want of harmony in the movements, without any expression of pain. On reaching the middle layers an almost universal agitation was manifested, without any sign of convulsion: the animal performed rapid and ill-regulated movements; it could

hear and see. After the removal of the deepest layers, the animal lost completely the power of standing, walking, leaping, or flying. The power had been injured by the previous mutilations, but now it was completely gone. When placed upon his back, he was unable to rise. He did not, however, remain quiet and motionless, as pigeons deprived of the cerebral hemispheres do; but evinced an incessant restlessness, and an inability to accomplish any regular or definite movement. He could see the instrument raised to threaten him with a blow, and would make a thousand contortions to avoid it, but did not escape. Volition and sensation remained; the power of executing movements remained; but that of co-ordinating these movements into regular and combined actions was lost.

Animals deprived of the cerebellum are in a condition very similar to that of a drunken man, so far as relates to their power of locomotion. They are unable to produce that combination of action in different sets of muscles which is necessary to enable them to assume or maintain any attitudes. They cannot stand still for a moment; and, in attempting to walk, their gait is unsteady, they totter from side to side, and their progress is interrupted by frequent falls. The fruitless attempts which they make to stand or walk is sufficient proof that a certain degree of intelligence remains, and that voluntary power continues to be enjoyed.

Rolando had, previously to Flourens, observed effects of a similar nature consequent upon mutilation of the cerebellum. In none of his experiments was sensibility affected. The animal could see, but was unable to execute any of the movements necessary for locomotion.

Flourens' experiments have been confirmed by those of Hertwig in every particular, and they have been lately repeated with similar results by Budge and by Longet. The removal of part of the cerebellum appears capable of producing the same vertiginous affection which has been already noticed in the case of deep injuries to the mesocephale. After the well-known experiments of Magendie, of dividing either crus cerebelli, the animal was seen to roll over on its long axis towards the side on which the injury was inflicted.

The effects of injuries to the cerebellum, according to the reports of the experimenters above referred to, contrast in a very striking manner with those of the much more severe operation of removing the cerebral hemispheres. "Take two pigeons," says M. Longet; "from one remove completely the cerebral lobes, and from the other only half the cerebellum; the next day, the first will be firm upon his feet, the second will exhibit the unsteady and uncertain gait of drunkenness."

Experiment, then, appears strikingly to favour the conclusion which Flourens has drawn, namely, that the cerebellum possesses the power of co-ordinating the voluntary movements which originate in other parts of the cerebro-spinal centre, whether these movements have reference to locomotion or to other objects.

That this power is mental, *i. e.*, dependent on a mental operation for its excitation and exercise, is rendered probable from the expe-

ience of our own sensations, and from the fact that the perfection of : requires practice. The voluntary movements of a new-born infant, lthough perfectly controllable by the will, are far from being co-ordiate: they are, on the contrary, remarkable for their vagueness and rant of definition. Yet all the parts of the cerebro-spinal centre are vell developed, except the cerebellum and the convolutions of the erebrum. Now, the power of co-ordination improves earlier and nore rapidly than the intellectual faculties; and we find, in accordnce with Flourens' theory, that the cerebellum reaches its perfect levelopment of form and structure at a much earlier period than the emispheres of the cerebrum.

It may be stated as favourable to this view of the mental nature f the power by which voluntary movements are co-ordinated, that, n the first moments of life, provision is made for the perfect perormance of all those acts which are of the physical kind. Thus, respiration and deglutition are as perfect in the new-born infant as in the full-grown man; and the excitability of the nervous centres to physical impressions is much greater at the early age, partly perhaps in consequence of the little interference which is received at that period from the will.

That the cerebellum is an organ favourably disposed for regulating and co-ordinating all the voluntary movements of the frame, is very apparent from anatomical facts. No other part of the encephalon has such extensive connections with the cerebro-spinal axis. It is connected slightly indeed with the hemispheres of the brain, but nost extensively with the mesocephale, the medulla oblongata, and he spinal cord. Now it is not unworthy of notice that its connection with the brain proper is more immediately with that part which we egard as the centre of sensation; namely, with the optic thalami, hrough the processus cerebelli ad testes. And it cannot be doubted hat the muscular sense materially assists in the co-ordination of novements.

The cerebellum is connected with the medulla oblongata and spinal cord by the restiform bodies, and the posterior columns of he cord, and with the mesocephale by the fibres of the pons. Thus his organ is brought into union with each segment of the great nervous centre, upon which all the movements and sensations of the body depend. It would be difficult to conceive any other function or which so elaborate a provision would be necessary, excepting hat of regulating and co-ordinating the infinitely complex movenents which the muscular system is capable of effecting; more espeially when it is plain that the antero-lateral columns of the cord and he anterior pyramids and olivary columns supply all the anatomical onditions which may be necessary for the development of acts of ensation and volition.

So far, then, we derive from experiment and from anatomy argunents highly favourable to Flourens' theory of the use of the cereellum. The results of pathological inquiry afford no satisfactory nformation on this point; for so closely connected are the transverse ibres of the pons with the anterior pyramids in the mesocephale, that

the morbid influence of any deep-seated lesion of either hemisphere of the cerebellum is very readily transferred to that segment, and produces symptoms precisely resembling those of lesion of either cerebral hemisphere. The signs referable to cerebellar lesion are therefore obscured by those which result from the affection of the pyramidal bodies. A few cases, however, have been put on record in which a tottering gait, like that of a drunken man, and a defective power of co-ordination existed in connection with a diseased state of cerebellum. (*Andral*, *Clin. Med.*, t. v. p. 428.)

It remains for us to notice the celebrated theory of Gall, that the instinct of propagation has its seat in the cerebellum; which, indeed, according to the author of the theory, and the majority of his followers of the phrenological school, is exclusively devoted to that function. We conceive that this view is far from admissible, on several grounds, of which the following deserve particular mention.

1. It is extremely questionable how far the sexual instinct admits of being separated from the emotions—from those especially which are clearly instinctive in their nature; and, even if it were separable from them, it seems scarcely of such importance, when compared with the other instincts, as to need a separate organ of great magnitude and of complex structure. If we compare it, for example, with the instinct of self-preservation, as manifested in providing either for the wants of the body, or for defence against assault, it certainly cannot be admitted to have a superior influence in the animal economy to this the most pressing of all. Yet it is not pretended to assign a separate seat even to this.

2. The nature of the generative instinct is scarcely such as to require in its central organ connections so extensive as those possessed by the cerebellum. It is not likely that this organ would be connected with any other part of the spinal cord than that from which nerves are derived to the organs of generation; nor is it conceivable that an instinct like this should require for its exercise fibrous matter in such large quantity as exists in the cerebellum, taking its rise from so great a surface of vesicular matter.

3. The generative instinct is not so pre-eminently developed in man as to account for the great superiority in size, as well as structure, of the human cerebellum over that of the lower animals, even of the mammiferous class. On the contrary, it may be safely asserted that this instinct is much more powerful in the monkeys, and also in the frogs; in the latter of which the cerebellum is absolutely very small, and especially so, relatively to the spinal cord and the cerebral lobes.

4. If the cerebellum be the seat of the generative instinct, it ought to exhibit marked indications of wasting, in cases where the genital organs have been mutilated; or where they have decayed in the natural progress of age. Yet the recorded cases of this nature are by no means conclusive; on the contrary, M. Leuret's remarkable observations show, that, in the gelding, the cerebellum is actually heavier than in either the stallion or the mare.

5. It does not appear, from pathological research, that the cerebel-

m has any peculiar influence upon the genital organs. Injury or sease of that organ very rarely produces any effect upon the penis; it lesion of the medulla oblongata or of the spinal cord is very apt occasion a semi-erection of that organ.

Of the Convolutions of the brain.—These, with the fibrous matter hich connects them with the optic thalami and corpora striata, form far the largest portion of the encephalon; and this fact alone ught to stamp them with great physiological importance. The comlexity of the convolutions in the animal scale is in the direct ratio f the advance of intelligence. It must be remarked, however, that he weight of the brain, whether absolute, or in relation to the body, ffords no criterion, or at best an imperfect one, of the extent of he convoluted surface. Highly complicated convolutions may exist long with a brain both absolutely and relatively small. Thus Leuret sserts, that the ferret, which has several well-marked convolutions n each hemisphere, has a brain no larger than that of the squirrel, which has no convolutions at all, and which wants even the few ssures which mark their first development in the rabbit, the beaver, he agouti, &c. And the last-named animals have the brain both bsolutely and relatively larger than that of the cat, the pole-cat, the roussette, the unau, the sloth, and the pangolin, all of which possess convolutions. We hence learn the physiological distinctness of these organs from the more deeply-seated gangliform bodies of the brain, to which we have already seen that separate functions may be ssigned.

At the early periods of human life, in infancy and childhood, the convolutions of the brain are very imperfectly developed, and their increase of size goes on simultaneously with the advance of mental power. If the former be arrested, or if some congenital fault prevent he further growth of the convolutions, the mental powers are of the owest and feeblest kind, but little above those of the brute with mperfect convolutions. In all idiots the brain is not only small, but ts convoluted surface is extremely limited.

We remark here that the convoluted form must be regarded no therwise than as a convenient mode of packing, which affords an ndication of a greater or less superficial extent of vesicular matter, or in cases where a slow and gradual accumulation of water takes lace within the ventricles of the brain, when accompanied with coresponding enlargement of the cranium, the convolutions become nfolded; and yet the intellect may remain unimpaired, at least so ar as the obvious damage to the *quality* of the nervous matter in uch cases will allow.

In examining the brains in the animal series, we observe a proressive increase in the complication of the convolutions, and therefore in the extent of the convoluted surface, as we pass from the nferior to the higher classes,—from those endowed with but feeble ntelligence to those which enjoy sagacity, docility, and memory. nstances have been already referred to of animals of the same group, lthough of different species, having brains very differently developed s regards the convoluted surface. In the animal with greater mental

power, the convolutions are always deeper or more complex (*vid.* p. 256).

If a similar comparison were instituted between the brains of different men, whose intellectual powers had been known, there can be no doubt that a similar result would be obtained. A series of outline views of the convolutions of the brain in various known individuals would be of great interest and advantage in reference to the question of their function.

Thus anatomy leads to the conclusion that the operations of the mind are associated with the convolutions. Perception, memory, the power of abstraction, imagination, all possess, as instruments of corporeal action, these folds of vesicular and fibrous matter. These parts, in the language of Cuvier, are the sole receptacle in which the various sensations may be as it were consummated, and become perceptible to the animal. It is in these that all sensations take a distinct form, and leave lasting traces of their impression; they serve as a seat to memory, a property by means of which the animal is furnished with materials for his judgments.*

It is quite established as the result of all the experiments upon the cerebral convolutions and the white matter of the centrum ovale, that mechanical injury to them occasions no pain, nor disturbance of motion. The endowments of the nerve-fibres which form the fibrous substance of the cerebral convolutions appear to be quite distinct from those of sensitive or motor nerves. They are internuncial between parts which are beyond the *immediate* influence of the ordinary physical agents, and which have no direct connections with muscular organs. And if, under the influence of morbid irritation, they do excite pain or convulsion, which is frequently the case in disease of the cerebral meninges, this is effected through a change produced in the corpora striata or optic thalami propagated to the origins of motor and sensitive nerves.

The recorded experiments upon the removal of the hemispheres of the brain do not lead to any satisfactory conclusion, as in all of them the corpora striata and thalami have been removed at the same time. But it may be here stated, that the effect of the removal of the hemispheres in Flourens' experiments was to throw the animal into a state of deep sleep, retaining its full muscular power, yet apparently incapable of a single mental nervous action, whether voluntary or sensitive.

When the membranes of the brain are in a state of inflammation, disturbance of the mental faculties is an invariable accompaniment to an extent proportional to the degree of cerebral irritation, and more especially so when the inflammation is seated in the pia mater of the convolutions. This disturbance of mind is frequently indicated by the manifestation of delirium of a more or less violent kind. It is plain that in such a case the delirium arises from the altered state of the circulation in the gray matter of the convolutions, the blood-vessels of which are immediately derived from those of the pia mater, so that the one cannot be affected without the other likewise suffering.

* Cuvier, Rapport sur le mémoire de Flourens sur le système nerveux.

ay be stated, as a fact no less interesting in a physiological ortant in a practical point of view, that in many, if not in stances of violent delirium, such, for example, as delirium the vesicular matter of the convolutions is found after death oodless, as if its wonted supply of blood had been comt off from it. Thus it happens in the delirium after great s—in that of rheumatic fever—and perhaps also of gout— at which occurs in the more advanced stages of continued

arn from the most trustworthy reports of the dissections of s of lunatics, that there is invariably found more or less f the vesicular surface, and of the pia mater and arachnoid tion with it, denoted by opacity or thickening of the latter, red colour or consistence of the former.

hese premises it may be laid down as a just conclusion, that olutions of the brain are *the centre of intellectual action*, or, ctly, that this centre consists in that vast sheet of vesicular hich crowns the convoluted surface of the hemispheres. ace is connected with the centres of volition and sensation striata and optic thalami), and is capable at once of being y, or of exciting them. Every idea of the mind is associated rresponding change in some part or parts of this vesicular and, as local changes of nutrition in the expansions of the pure sense may give rise to subjective sensations of vision g, so derangements of nutrition in the vesicular matter of ce may occasion analogous phenomena of thought, the rapid ent of ideas, which, being ill-regulated or not at all directed ll, assume the form of delirious raving.

ctions of the convoluted surface of the brain, and of the nnected with it, are altogether of the mental kind. The changes in these parts give rise to a corresponding mani- of ideas; nor is it likely that any thought, however simple, mpanied by change in this centre. The shock of concus- r checks the organic changes of the vesicular surface, and lso of the fibrous matter, as to interrupt for a time those ctions of the mind and the brain which are necessary for onsciousness. The condensation of the substance of the res which is produced by an apoplectic clot, or by the effu- me other foreign matter, prevents a similar consent of action, gives rise to the phenomena of *coma*, in which all mental actions are destroyed or suspended. Those parts of the pinal centre on which the physical actions depend, being npletely protected from compression, do not suffer in their , and consequently actions of this kind remain unimpaired.

iew of the function of the convolutions of the brain has been nearly all the great anatomists who have directed their ions to this wonderful organ. Our countryman, Willis, advanced this opinion in the seventeenth century, and ed that the various gyrations were intended for retaining the irits "for the various acts of imagination and memory"

within certain limits. The distinguished Gall, however, proposed to assign certain convolutions as the seat of certain faculties of the mind—moral feelings, or instinctive propensities—and upon this basis raised the celebrated theory of Phrenology, which has been pursued since his time with all the zeal and interest naturally attaching to a science which professes from external signs to detect the natural tendencies of the spirit within.

We do not propose to discuss the validity of this theory, which seems to have been taken up with more apparent zeal for victory, than love of truth. But we shall remark, that, in considering the truth or falsehood of Phrenology, it is absolutely necessary to separate the metaphysical question—as to the existence of certain faculties of the mind—from what has been admitted as a physiological fact before the foundation of the phrenological school, that the vesicular surface of the brain is the prime physical agent in the working of the intellect. A physiologist may hold the validity of this latter doctrine, and yet think as we do, that many of the so-called faculties of the phrenologists are but phases of other and larger powers of the mind; and that the psychologist must determine what are, and what are not, fundamental faculties of the mind, before the physiologist can venture to assign to each its local habitation. The empirical method, by which Gall first fixed upon certain parts of the brain as the seat of certain faculties, is exposed to this serious fallacy, that a part on the surface of the brain may appear largely developed, by reason of the large size of some subjacent or neighbouring part. We have already shown how this may be the case with reference to the cerebellum, and that a thick neck and large occipital region may, and probably do, indicate a large mesocephale more frequently than a large cerebellum. At the same time we think that all observation, both in man and in the lower animals, proves that the energy of any nervous centre always bears a direct proportion to its bulk, whether absolute or relative; and that the phrenologists do not err in attaching great and primary importance to the size of those parts with which they associate certain faculties: while the attention which recent writers of that school have paid to the temperaments of the individuals under examination, is a proof of their admission that the *quality* of the nervous matter constitutes a highly important element in the development of nervous power.*

We have seen that the convoluted vesicular surface, and the fibres of the centrum ovale, are the seat of those physical changes which accompany, and are necessary to, intellectual action. A large number of these fibres is commissural, but the greatest proportion of them serves to establish a communication between the centre of intellectual action, and the centres of volition and sensation. Through the connection with the former the intellect may prompt or excite the will; and the will, on the other hand, may control, direct, or apply the powers of the intellect. The faculty of Attention, and, therefore, in

* Carus has lately propounded a new Cranioscopy, founded upon the tripartite composition of the cranium, which bids fair to rival the system of Gall. See a Lecture in Lond. Med. Gazette, vol. xxxiv., translated by Dr. Freund.

ain degree, the power of Memory, are dependent on the influ-
of the centre of volition upon the centre of intellectual action.
one is sensible of a power which he possesses of fixing his
ion on any given subject, as distinct as that by which he can
act any particular muscle. Again, the association of the intel-
l centre with that of sensation is necessary to ensure the full
ption of sensitive impressions. The experience of each indi-
l can supply him with numberless instances in which, while
ind was employed upon some other object of interest, an im-
on was made upon some one of the organs of sense, and indis-
y *felt*, but not fully perceived. When the mind has become
gaged, the fact that an impression had been made is remembered,
ut any ability to recollect its precise nature. And in many
ics the centre of intellectual action is so impaired as to destroy
eatly reduce the power of perception, whilst there is abundant
nce to show that the affections of the organs of sense still make
ficient impression on the centre of sensation. In some cases,
ver, this centre likewise participates in the general hebetude.
rfect power of speech, that is, of expressing our thoughts in
le language, depends upon the due relation between the centre
lition and that of intellectual action. The latter centre may have
ower to frame the thought; but, unless it can prompt the will
ertain mode of sustained action, the organs of speech cannot be
ht into play. A loss of the power of speech is frequently a
rsor of more extensive derangement of sensation and motion.
me cases the intellect seems clear, but the patient is utterly
e to express his thoughts; and in others there is more or less of
l confusion. The want of consent between the centre of intel-
l action and of volition, is equally apparent in cases of this
ption, from the inability of the patients to commit their thoughts
iting.

hemispheres of the brain, as has been already stated, are
ible to pain from mechanical division or irritation; in wounds
cranium in the human subject, pieces of the brain which had
ded have been removed without the knowledge of the patient.
theless, pain is felt in certain lesions of the brain, even when
in the substance of the hemispheres, or in the optic thalami or
ra striata. This results from the morbid state affecting other
with which nerves are connected, as the medulla oblongata; or
ich nerves are distributed, as the membranes. The nearer a
al lesion is to the membranes or to the medulla oblongata, the
likely is it to excite pain. Headaches, of whatever nature, must
erred to irritation either at their centres or at their periphery, of
nerves which are distributed in the dura mater, or in the scalp.
ranches of the fifth pair, of the occipital nerve, and the auricu-
anch of the cervical plexus, are those most frequently affected.
tain sensations are referred to the head which may occur from
rbid state, or may be produced by changes of position in the
Such are, vertigo, a sense of fullness, or of a weight in the
a feeling of a tight cord round the head. These are, no doubt,

truly subjective, arising from alterations in the distribution or in the quality of the blood sent to the brain. A sensation of a rushing of blood to the head is often consequent upon excessive hemorrhage, or accompanies a state of extreme debility from any cause. This is owing in great part to the feeble tone of the arteries, resisting imperfectly the flow of blood to the head, and allowing it to impress the nervous matter too much. It is well known, that, by turning round quickly on one's own axis, the sense of *vertigo* may be produced,—a confused feeling in the head, and an inability to maintain perfectly the balance of the body, accompanied by an appearance as if external objects were revolving. If the eyes be kept shut, the uneasy feeling of the head will take place, but no true vertigo. To obtain this feeling perfectly, the eyes must be open, and objects presented to them. And Purkinje has shown that the direction in which external objects appear to revolve is influenced by the position of the body and of the head while turning round, and by the position of it afterwards, when the experimenter has ceased to move round. If the experimenter have kept his head in the vertical position while moving round, and afterwards when standing still, the objects appear to revolve in the horizontal direction. If the head be held with the occiput upwards while turning round, and then erect when standing still, the objects seem to rotate in a vertical plane, like a wheel placed vertically revolving round its axis. (*Müller's Physiology*, by Baly, vol. i., p. 848.) It is highly probable that these sensations, as well as those which arise spontaneously, are due to some irregular distribution of blood to various parts of the brain. A sense of giddiness frequently precedes fainting, and is attributable to the temporary deficiency in the supply of blood to the head. If the horizontal position be immediately adopted, or the body be laid with the head inclined downwards, the faint may be prevented. The sense of giddiness which is experienced upon rising from the horizontal position after illness, is doubtless of the same kind. Anemic patients experience this feeling of giddiness even in the horizontal posture;—and both it and the headache and delirium, which accompany this state of bloodlessness, may be somewhat relieved by placing the patient on an inclined plane with the head downwards.

The mind possesses a remarkable power of exciting and of exalting painful sensations in various parts of the body. If the attention be directed very strongly, and for some time, to any part, that part may become the seat of pain, for which the most effective remedy is to engage the thoughts as much as possible on some other object. In many instances, where pain has been excited by a physical cause, there can be no doubt it has been continued long after the cessation of its exciting cause, by the attention of the patient having been directed to it. It is probable, that in such cases the *perceiving* parts of the brain (so to speak) become habituated to a certain condition of the centre of sensation, produced by the original exciting cause of the pain.

Nerves are implanted only in those parts of the encephalon which are capable of physical nervous actions: the convolutions of the

the corpus striatum, the optic thalamus, and the cerebellum, apable only of mental nervous actions. In every change of latter, the mind is either the excitor or excited; the conditions e nerves involve them only through the influence of the centres iich the nerves are implanted; and they affect the nerves only gh the same medium. Matteucci's experiments as to the effects ectricity on the different parts of the brain, showed that, as long e current was confined to those parts which are capable only of al actions, no apparent effect was produced. But when the s of the battery had penetrated to the base of the brain so that urrent might pass through the deeper seated parts, then the animal l out with pain, and strong convulsions were produced.

hose parts in which physical nervous actions take place, (although ible of partaking in the mental actions,) require the excitation of ical stimuli in order to develop their peculiar phenomena, and have frequent remissions in the active performance of their func- in the frequent absence of the ordinary stimuli. But the ever- e mind keeps up a constant and proportionally rapid train of ges in those parts which are more especially connected with al actions: hence these parts, requiring repose, fall at certain ds into that peculiar and inscrutable state called *sleep;* in which, ever be the condition of the mind itself, the brain either refuses, slow to respond to its stimulation, or to convey impressions to In deep sleep we are completely unconscious, and may remain considerable time motionless. But, as the accustomed period pose approaches to its termination, the sleep becomes lighter, a e of consciousness returns, and mental changes take place, h, whether incoherent or connected, constitute what are fami- known as dreams. In lighter sleep, it cannot be said that is complete want of consciousness; nor is the mind, although aratively quiescent, in complete repose. The readiness with h, at times, some persons, during sleep, reply when addressed, esume the waking state,—the power which many unquestionably of limiting the duration of sleep to a predetermined period, as asted with the deep unconsciousness and slowness to awake of s,—strongly favour this idea.

iis state, with which the revolution of each diurnal period makes miliar as one of repose to the great centres of mental nervous ns—"tired Nature's sweet restorer"—occurs, with modifications, e result of certain morbid processes, as the effect of certain phy- agents, or even as the consequence of peculiar states of mind. , under the influence of pressure, from a clot of blood compress- he brain, or from lymph or fluid at its base, a state varying from of drowsiness up to the profoundest sleep, or *coma*, may be in- d. Whatever be the nature of the compressing substance, or ever situate, if the hemispheres experience general pressure, this t will ensue. Again, a class of drugs, of the sedative or narcotic , exerts a similar influence; and, if given in too large a dose, paralyze the brain. We have daily evidence of this in the effects pium, which paralyzes at first the centres of mental actions, and

ultimately those of physical actions. Lastly, particular states of the system, induced, perhaps, by deranged assimilation, or by great previous disturbance of mind, dispose persons to fall into that state which is called *somnambulism*. The somnambulist is one who dreams, and acts in his dream as if he were awake, and as if all the phenomena presented to him were real. He appears to the bystanders in a deep sleep, but acts with wonderful precision, walks with steady gait, and avoids obstacles. Yet frequently accidents, injurious or even fatal, occur; which show that on such occasions he is asleep, and has not the *full* command of his senses. Persons in this state will answer questions rationally and with readiness, and do not appear to be at all disturbed by being questioned. The hypochondriacal or hysterical diathesis disposes greatly to the development of somnambulism both in male and female.

A state remarkably analogous to this of somnambulism may be induced in persons of nervous temperament, which has been called the *Mesmeric sleep*, or trance. It requires for its production the apparent influence of another individual, who watches the person experimented on with an intent look, and makes certain movements before him, which are called *passes*. All persons are not susceptible of passing into this state, any more than they are of exhibiting the phenomena of somnambulism. The same state of constitution which disposes to the latter is favourable to the former. Remarkable statements have been made, and confirmed by the testimony of a large number of observers, tending to imply that in these cases the faculties become exalted in an extraordinary manner; and that the individual acquires powers of a novel description, and even of a superhuman kind. It behoves all sober-minded persons to be slow to accept such statements as true, and, without impugning the veracity of the reporters, to inquire whether they do not rest more upon a misinterpretation than upon a misrepresentation of facts. The polar force of the mental nervous centres may, in this peculiar state, be so affected as to favour the development of subjective phenomena, which it is evident may assume particular forms under the influence of impressions made from time to time upon the senses. The ravings of a delirious or of a lunatic patient often take a particular direction under the influence of a question or remark let fall by some bystander; it is not unlikely that persons, with a mental bias for the marvellous, might discover in such patients quite as much evidence of superhuman power, as has been adduced by the Mesmerists.

We cannot avoid remarking how much it is to be lamented that inquiries of so delicate a nature, affecting the very confines between mind and matter, should have usually fallen into the hands of persons ill qualified for such pursuits, either by mental constitution or by previous experience in the study of subjects involving both physical and metaphysical knowledge. Little is to be expected in such difficult researches from *dilettanti* of either sex; much less from those whose excessive zeal for novelty and notoriety must necessarily cast suspicion on their statements. Nor can we hope that truth can be elicited from experiments and observations which are made before

the public gaze, with more of the characters of a theatrical exhibition than of a sober philosophical investigation.

Functions of the Commissures.—The commissures of the brain have long been regarded as provisions to ensure the harmonious co-operation of certain parts of the nervous centres, whether on the same or on opposite sides. This opinion rests mainly upon their anatomical connections; for but little that is satisfactory can be concluded from either the comparative anatomy or pathological conditions of them. It is evident that the principal commissures bear a direct ratio in point of development to that of certain parts; and that, when those parts are imperfect or absent, the commissures are deficient or wholly wanting. Thus the corpus callosum and the hemispheres are developed together; the fornix and the hippocampi, the pons Varolii and the cerebellar hemispheres.

The anatomy of the corpus callosum favours the hypothesis that it is the bond of union to the convoluted surface of the hemispheres, and that it is the medium by which the double organic change is made to correspond with the working of a single mind. There is nothing in the recorded observations of morbid change or congenital defect of this part to militate against this idea; but it must be remarked that all these cases are accompanied with lesion or defect of other parts, which weaken the inferences to be drawn respecting the corpus callosum. Direct experiments upon this commissure yield only negative results. Longet and others found that irritation of it did not cause convulsions: and Longet states, that injury to the corpus callosum in young rabbits and dogs did not appear to disturb voluntary movements; and that, when he incised this body in its whole length in rabbits standing, they have continued to maintain that position; or, when urged on, ran; and that no convulsive movement whatever, nor any sign of pain was manifested. Such statements are certainly favourable to the supposition that these fibres are destined to connect centres whose appropriate stimulus is mental.

The fibres of the fornix manifest the same insensibility to mechanical irritants; and their obvious anatomical connection with particular convolutions warrants but one conclusion, that they associate the actions of those parts. Lallemand relates a case in which the symptoms were altogether limited to mental disturbance, without any affection of the sensitive or motor powers, and the fornix and corpus callosum were found in a state of complete softening without discoloration.

The fibres of the pons Varolii bring the cerebellar hemispheres into connection with each other, and with the vesicular matter of the mesocephale. Direct experiments on these fibres can yield no satisfactory result, because they are so intimately associated with the deeper seated parts of the mesocephale, and with the nerves of the fifth pair and others, that it is impossible to irritate them in the living animal without likewise irritating these other parts. And it is sufficiently evident that these fibres have no necessary connection with sensation and volition, from their non-existence in birds; nor even with the cerebellum *when that organ is single.* It will be borne in

mind, that at a previous page we have referred to the connection of these fibres with the mesocephale as explaining the crossed influence of lesion of one hemisphere of the cerebellum.

We conclude this chapter with the following inferences, which, we think, the present state of knowledge justifies:

1. The spinal cord contains within itself all the physical conditions necessary for the mental and physical actions of the trunk and extremities, so long as its connection with the encephalon is perfect through the anterior pyramids.

2. There is no sufficient evidence to prove the existence of a class of sensori-volitional fibres distinct from those which are the instruments of physical actions.

3. Each segment of the cerebro-spinal centre, whether in the cranium or in the spinal canal, gives origin to its own proper nerves, and has no connection with the neighbouring segments, otherwise than by commissural fibres or vesicular matter.

4. The antero-lateral columns of the cord, with the anterior and posterior horns of the gray matter, are the effective centres of motion and sensation of the trunk and extremities. The posterior columns are longitudinal commissures by which the influence of the cerebellum is brought to bear on the various segments of the cord.

5. When the pyramids are in a state of integrity, the corpus striatum, certain accumulations of gray matter connected with the nerves of the medulla oblongata, the locus niger, and the anterior horns of the spinal gray matter are the centres of voluntary motion to the whole body; while the optic thalami, olivary columns, and posterior horns of gray matter are the centres of sensation.

6. The medulla oblongata, when connected to the corpora striata by the pyramidal fibres, is a centre of voluntary actions to those parts whose nerves are derived from it; and, in addition, it is the principal centre of the actions of respiration and deglutition.

7. The corpora quadrigemina are primary centres of visual impressions, and, with a large portion of the gray matter in the mesocephale, are centres of emotional actions.

8. The cerebellum is the co-ordinator of voluntary and locomotive actions.

9. The convolutions of the brain are the centres of intellectual actions, and are intimately associated with the mental phenomena of attention, association, and memory.

On the subjects discussed in this chapter we refer to the more recent treatises on Physiology, by Müller, Wagner, and Carpenter;—to Dr. Marshall Hall's writings on the Nervous System; the most important of which will be found in an octavo volume "On the Diseases and Derangements of the Nervous System," 1841; and in a quarto volume "On the Nervous System," 1843;—to Henle's General Anatomy;—Whytt on vital motions;—Prochaska, Annot. Academicæ;—Le Gallois, Œuvres;—Flourens sur le système nerveux;—Desmoulins et Magendie sur le système nerveux;—Longet, Anat. et Physiol. du système nerveux;—Volkmann, in Müller's Archiv.;—Van Deen, sur la Physiol. de la Moëlle Epiniere, and the works referred to at the conclusion of the last chapter.

Appendix to the Eleventh Chapter.—Whilst the preceding pages were passing through the press, we were favoured, through the kindness of Prof. Matteucci of Pisa,

several opportunities of witnessing his highly important electro-physiological :riments. As these experiments tend very much to confirm and substantiate the rs expressed in Chap. IX., we subjoin here a succinct account of them.

he facts which M. Matteucci's researches have developed are the following:—1. t muscle is a better conductor of electricity than nerve, and that nerve conducts :r than brain. 2. That in the muscles of living animals, as well as of those re-ly killed, an electric current exists, which is directed from the interior of each ele to its surface. 3. That in frogs, a current exists peculiar to the Batrachian iles, which proceeds from the feet to the head, and is distinct from the muscular ent. 4. In continuation of Marianini's and Nobili's researches, Matteucci illus-:s the effects of the inverse and direct currents in nerves of different function, and rs very strikingly the difference in the influence of the electrical stimulus upon 'es, from that of other stimuli upon these organs.

or these researches Matteucci employed the galvanometer of Rumkorff (Paris), :h is the same as that of Nobili with the addition of a small apparatus, by means rhich the needles may be rendered more or less astatic, and thus the sensibility he galvanometer may be more or less increased. But he also takes the pre-.ion, to guard against the development of currents by unequal chemical action a the poles of the galvanometer, to have them made of plates of platina, which is acted upon by water or saline solutions. He takes two plates of platina, about a rter of an inch in breadth, and fixes each in a handle of wood. The plates are soldered to the wires of the galvanometer, and both the handles and the plates covered with a layer of sealing wax-varnish, leaving only a space of about a rter of an inch uncovered at the extremity of each platinum plate.

he frog's leg, prepared in a certain way, is most susceptible of electric influence, therefore may be used as a galvanometer of extreme delicacy. The skin is strip-off one lower extremity of a lively frog, and the whole length of the sciatic nerve is ected out from among the muscles of the posterior part of the thigh; after which, thigh is cut across just above the knee, the nerve remaining attached to the knee leg. The leg is now placed in a glass tube, in such a position that the nerve gs loosely from the end of the tube. To use this galvanoscope, the operator holds glass tube at the opposite extremity to that in which the leg is placed, and causes nerve, which hangs loosely from the tube, to touch at two points the electromotor rent under examination. If the nerve be traversed by a current, the leg instantly racts. This apparatus, called by Matteucci *grenouille galvanoscopique*, is the t delicate we possess, if it be renewed from time to time. And it is capable, not of indicating the existence of an electric current, but also of showing, with a t degree of probability, the *direction* of that current. When the frog has become .tle weakened, it almost constantly happens that the contraction takes place on ng the circuit, if the current pass from the nerve to the leg; but if it pass from eg to the nerve, contraction will take place on *opening* the circuit.*

Matteucci's experiments upon the relative conducting power of animal sub-ces, were founded upon a law of derived currents. When a liquid, or any other r, is traversed by an electric current, and the plates of the galvanometer are ged into it, there are immediate indications of a *derived* current, so directed in the anometer, that the point at which it enters the coil of the galvanometer, corre-ids to the positive pole of the current which traverses the liquid. The derived ent is always greater, as the plates of the galvanometer, plunged in the liquid, more distant from each other. If a current be made to traverse different sub-ces, which correspond as nearly as possible as regards shape, bulk, etc., the de-d current from each will be exactly in the inverse ratio of the conducting power he substance traversed.

ieces of nerve, brain, and muscle, from a rabbit just killed, were selected for the parative experiments; these were cut so as to correspond as nearly as possible oint of size and shape, and disposed as a chain on an insulating plane. Platinum :s, fixed by sealing-wax to two pieces of cork, which were held apart at a certain ance by a rod of glass which transfixed each of them, were soldered to the wires he galvanometer, the platinum wires having been previously varnished to within :ry short distance of their extremities. A current from twelve cells of a constant ery, was now passed through the chain of animal substances. The platinum :s, held always at the same distance from each other, were successively brought

* Those who propose to employ the galvanometer in physiological experiments, should fully observe the precautions assigned by Matteucci, in the third chapter of his book, ard against erroneous inferences.

into contact with brain, nerve and muscle, and the deviation of the needle resulting from the derived current in each case was carefully noted. The derived current from nervous matter was always greater than that from muscle: that from brain greater than that from nerve, denoting a less conducting power in nervous matter than in muscle—in brain than in nerve. By increasing the distance between the platinum wires, a derived current may be obtained from muscle equal to that obtained from brain; and Matteucci, from this latter experiment, infers that the conducting power of muscle may be taken as four times greater than that of brain or nerve.

Another interesting experiment confirmed the results obtained from those just detailed. The current was made to traverse the whole trunk of a rabbit just killed and flayed, and the platinum wires, held at a constant distance, were applied successively to different parts, muscles, nerves, etc.; the current was found to traverse all parts, with such difference as was due to the different power of conduction of the different substances; that is, so as to yield a derived current of less intensity from muscle than from nerve, or from nerve than from brain.

2. To demonstrate the existence of an electric current in the muscles of animals recently killed or living, the following experiments have been adopted by Matteucci.

If a deep wound be made in a muscle of any living animal, and the nerve of the galvanoscopic frog be introduced into it, so that the nerve shall touch the cut surface at one point, and the outer surface of the muscle at the other, contractions instantly take place on completing the circuit. It is evident that this effect is due to an electric current developed by the muscle, because it is necessary that the nerve should touch the muscle at two points; and because, if the nerve be brought into similar contact with two points of any other body, no such effect will follow. To guard against the fallacy that might arise from contact with the blood, Matteucci shows, that if a nerve be brought into contact with a layer of blood at two different points, no evidence of an electric current will appear. In this, and all experiments with the galvanoscopic frog, it is to be remembered that the frog's leg must be held in the glass tube to insure perfect insulation. The experiment is always followed by the same results, whatever be the muscle or the animal touched, or even if muscles separated from the animal be operated on. The indications of the electric current remain longest in those animals in which the muscular contractility lasts longest; in cold-blooded animals, such as fish and reptiles, Matteucci has seen the phenomena last for many hours. The current is sufficient to excite the nerve of a warm-blooded animal. The thighs of a rabbit having been removed, a long portion of the crural nerve was dissected out, and the muscles exposed. With a glass tube the nerve was raised and brought to touch the muscles at two points, when the whole limb was thrown into contraction.

So far, distinct evidence was afforded by the animal galvanometer, (so to speak,) of the existence of a muscular current. When the frog's leg becomes a little weak, it indicates the direction of the current to be from the interior to the surface of the muscle.

In order to demonstrate the influence of this current on the galvanometer, a particular arrangement is necessary.

Several small cup-like cavities are scooped out in a piece of wood, twelve inches square, and an inch and a half thick. The wood and its little cavities are coated over with a layer of varnish, or small capsules sunk into the wood may be employed. Five or six frogs are prepared, by flaying the posterior extremities, and the legs are separated by disarticulating them at the knee; which must be done with care, in order not to wound the mass of crural muscles. Next, each thigh is divided at its middle, and thus a certain number of conical masses (the lower halves of the thighs) are obtained. These must be arranged on the board in a chain. One half-thigh is placed at the edge of one of the cavities, with its apex to the cavity, and the cut surface outwards; and the chain is completed by arranging the others in a semicircle, so that the apex of one freely touches the cut surface of the other, and the piece which forms the opposite extreme of the series ought to touch the edge of another of the cavities by its cut surface. Thus, a pile is formed, of which one of the extremities is the interior of the muscle, and the other its external surface. The board, with the muscular pile arranged upon it in this way, is now brought to the galvanometer, the platinum poles of which, if it be a very sensible one, have been some time placed in distilled water; or, if not very sensible, in a saline solution. The next step of the experiment is with a pipette, to pour into the cavities with which the extremes of the pile are connected, either water or some of the saline solution, according as the plates of the galvanometer have been immersed in either of those fluids.

The platinum poles of the galvanometer are now withdrawn from the fluid in which they had been immersed, and introduced into the fluid of either of the cavities; if no deviation of the needle follow this, they are at the same time plunged into the two extreme cavities of the pile, so as to close the circuit. A deviation of the needle takes place immediately, which varies in amount according to the number of segments which constitute the pile. Matteucci has obtained a deviation of 15°, 20°, 30°, 40°, 60°, etc., according to the number of half-thighs, supposing the frogs employed to be equally lively; he obtained 3° or 4° with two elements, 6° or 8° with four elements, 10° or 12° with six, and so on. These numbers are obtained, using distilled water in the cavities; but the deviation may be increased considerably if a few drops of sulphuric acid be added to it, so that a pile of eight half-thighs, which gave a deviation of 15° with distilled water, will cause 50° with the acid liquid. When the fluid was slightly saline or alkaline, the same number of elements caused a deviation of 35°. In all the trials the current had the same direction—that is, from the internal part of the muscle to its surface.

The muscular current may be demonstrated with the muscles of other cold-blooded and of warm-blooded animals. In all cases it is necessary so to arrange the elements of the pile, that the inner surface of one segment shall be in contact with the outer surface of the next, and that the inner surface of a piece of muscle shall form one pole, and the outer surface of another piece the opposite pole.

The duration of the muscular current corresponds with that of contractility. In cold-blooded animals, therefore, it is greatest. In mammalia and birds it is very brief. Temperature has a considerable influence upon the intensity of the current. If frogs are placed for some time in a very cold medium, piles made from their muscles yield no evidence of electricity; but, if the frogs are placed in a warm medium for a short time after they have been taken from a cold one, the current of electricity obtained from their muscles will be stronger than that from a similar pile which had not been subjected to any change of temperature.

Any circumstances which enfeeble frogs, and derange their general nutrition, will diminish the power of the muscles to generate electricity, as they also impair the contractile force. Thus, Matteucci found the great heat of summer to impair materially the development of electricity. We have found the same result in frogs which, having been kept crowded together in a small compass during the month of December, became ill-nourished, with soft, flabby muscles, full of moisture. The redder and more consistent the muscles are, as Matteucci remarks, the more distinct will be the signs of electricity.

The muscular current appears to be quite independent of the nervous system. The segments of which the piles are formed, are obviously beyond the influence of the nervous centres; and Matteucci has taken great pains to remove from such segments all the larger nervous trunks and filaments distributed among the muscles without affecting the electrical current. And in frogs, in which the lower part of the spinal cord had been destroyed by burning, there was no evidence of impairment of the electric current in the muscles of the lower extremities.

Matteucci found that narcotic poisons, in moderate doses, had little or no influence upon the muscular current. On one occasion, he found it slightly increased in a frog to which a very small dose of opium had been given. In very strong doses, such as to kill the animal, the muscular current is destroyed. The influence of the narcotic gases upon the current is of no importance, with the exception of sulphuretted hydrogen, which has the effect of materially weakening its intensity.

On one occasion, we endeavored to obtain a current from a pile composed of pieces of human muscle from a leg that had just been amputated; but the muscles were in so atrophied a condition, that the experiment failed with the galvanoscopic frog, as well as with the galvanometer. We have since learned from Professor Matteucci, that he has obtained evidence of the current in human muscle under similar circumstances.

It is plain, from the statements above given, that the essential condition for the full development of the muscular current, is a healthy and vigorous state of the muscles themselves, and that the nervous system contributes to the electrical phenomena only so far as it contributes to the healthy nutrition of the muscles by promoting their natural actions. The muscular current is one of the phenomena which attend the passive contraction of muscles; it disappears from dead muscle, and from living muscles which have so suffered in their nutrition as to lose their characteristic property. All external influences which materially affect the nutrition, and therefore the passive contraction of muscles, exert a corresponding effect upon the muscular current. The duration of the current after systemic death, continues in the different animals just so long as the phenomena of contractility are present.

3. In the latter part of the last century, Galvani announced his celebrated experiment, of causing contraction of the frog's leg by bringing its muscles in contact with the lumbar nerves. The following are the steps of this experiment: The integuments are stripped off the lower extremities, which are separated from the trunk at the middle of the back; a small portion of the lumbar region of the spine, from which the lumbar nerves emerge, is left with these nerves in connection with the lower limbs, the pelvis having been cut away. If, now, the limbs be suspended by the segment of the spine, and one leg be carefully bent up, so as to bring the foot into contact with the lumbar nerve, the whole limb is convulsed at the moment of contact. The foot may be made to touch the muscles at various parts of the limb without any such effect. The contraction is general, and evidently of the same nature as that which the passage of an electric current through the lumbar nerves would produce. When the experiment is carefully tried, it is impossible that the nerve can experience any mechanical dragging, such as would produce an effect like that described. Galvani pointed out, that, in order to succeed perfectly in the experiment, it is necessary to wait until the frog has recovered from the tetanic state which is likely to ensue upon the necessary mode of preparation. He also stated, that the experiment is more likely to be successful if the frog have been previously moistened by a solution of salt; and that the contraction of the muscles may be produced if the nerve and foot are connected by a piece of muscle, and not directly. The accuracy of Galvani's observations has been fully established by Humboldt, Valli, and many modern experimenters. We have frequently repeated the experiment with the same result.

Fifty years after Galvani, Nobili* took up the same line of inquiry. Having prepared the legs of a frog according to Galvani's method as above described, he plunged the lumbar nerves into one capsule and the feet into another, the capsules being filled with water. When the poles of a galvanometer were introduced into the fluid of the capsules, a deviation of the needle followed to the extent of 5°, 10°, or 15° or more. The deviation could be increased by making a chain of frogs' legs prepared in the same way. The legs were placed on an insulating plane, so that the nerves of one touched the feet of the next, and so on. It is necessary that the extremities of this pile should be plunged into capsules filled with water. Or, a pile may be made with a series of capsules containing water, connected together by frogs' legs; the nerves being placed in one, and the feet in the next. With such piles, a deviation of the needle to the extent of 60° may be obtained; or to a much greater extent, if, instead of distilled water, a weak solution of salt be employed to fill the capsules; or still more, if the fluid of the capsules be slightly acid.

In all these experiments the direction of the electric current was found to be constant, from the feet to the head. At the same time that the needle was made to deviate, the frogs' legs, whatever be the number constituting the pile, are thrown into contraction. It is not necessary for the production of the phenomena that the several legs should touch one another; it will suffice if they be connected by a conducting material, such as a skein of cotton moistened, wire, wet paper, or even water.

Nobili found that these signs of an electric current continued for many hours after the preparation of the animal. He distinguished the current by the title of *le courant de la grenouille, ou courant propre;* and he attributed it to a thermo-electric current caused by the unequal cooling of the nerve and muscle produced by evaporation.

It is evident that the experiment of Nobili is essentially the same as the original one of Galvani. In the latter the electric current was brought to act upon the nerves of the limb; in the former, upon the galvanometer.

The galvanoscopic frog may be used as a test of the electric current when Nobili's arrangement is preserved. If the extremes of the pile be connected by the nerve of the galvanoscopic limb, the instant the circuit is completed, its muscles will contract; and, as in other experiments with the galvanoscopic frog, we may determine the direction of the current when the frog becomes a little weakened.

Matteucci gives the name "*contraction propre*" to the contraction of the muscles which takes place in the frogs' legs, whether used singly or as a pile, at the same time that the deviation of the needle occurs. In order to obtain this phenomenon, the lumbar nerves must not be plunged completely in the water; otherwise the proper current circulates without passing through the nerves, and consequently the contractions do not take place, or are extremely feeble. These contractions continue, generally, only for ten or fifteen minutes, but rarely for half an hour after preparation.

Nobili has stated, that in arranging the frogs, so that the nerves of one touched those of the other, or the muscles came in contact with muscles, no contractions

* Bibliothèque Universelle, 1827.

ensued, because, as he explained, the electromotor elements were opposed. In Matteucci's hands, however, such a result was not obtained. If care be taken not to oppose to each other the nerves or muscles of symmetrical parts, contraction will always ensue.

The following is Matteucci's mode of showing this remarkable experiment. The limbs of a frog are prepared in the ordinary way; but, in addition, the heads of the thigh-bones and the ilium are completely removed, so as to leave the legs connected to each other only by the nerves, through the portion of the cord which is contained in the segment of the spine which remains. The parts are placed on an insulating plane. If the muscles of one leg are made to touch the other *thigh*, contractions ensue; but not so if the leg of one side touch the *leg* of the other. Or the same effect may be produced by bringing the different parts of the limbs into connection by moist paper or cotton; or, if the galvanometer be employed, signs of a current are afforded, by touching a thigh with one pole, and the opposite leg with the other.

In these experiments, when the frog is lively, contractions are produced, in touching the muscles of the thigh with those of the leg, as well on opening as on closing the circuit. But when it has become weak, contractions take place in one limb on closing the circuit, and in the other on opening it.

Matteucci explains the failure in producing contractions by touching corresponding parts, on the supposition that, under such circumstances, the currents of the two limbs circulate with equal intensity, and in a contrary direction. This he proves by the following experiment: If the frogs' legs, prepared as above described, are severed from each other, and the nerve of one leg and the foot of the other are placed in one capsule filled with water, while another capsule receives the other nerve and foot; the moment the circuit is completed, strong contractions in both limbs are produced. But to the galvanometer no sign of an electric current is afforded when its poles are plunged into the capsules. "In this case," says Matteucci, "the currents of the two limbs circulate together, passing equally through the limbs; and if even the parts of the current were to take the course of the galvanometer, it is easy to see that they would circulate in it in opposite directions, and therefore would produce no deviation. If, on the contrary, the disposition of the two limbs be such that the nerves are placed in one vessel, and the feet in the other, it is easy to see that the two portions of the current which do not circulate through the animal arc, enter the extremities of the galvanometer, and circulate in it in the same direction. It is the sum of these two portions which constitutes the proper current of the frog, which sum is measured by the galvanometer.

If several frogs' legs be arranged with opposed nerves and feet in the two capsules, the effect upon the galvanometer is not increased.

Comparative experiments as to the difference of the currents in piles formed of both the lower extremities of frogs, as already described, and in piles formed of an equal number of single extremities, showed no greater effect upon the galvanometer in the one case than the other.

From these and numerous other experiments, varied with great ingenuity and skill, Matteucci draws these conclusions:—1, that the complete electromotor element in the current of the frog is formed by one of its limbs—that is, of one leg, the thigh, its spinal nerve, and a piece of its spine;—2, that the current of one limb circulates by the other every time that, leaving the frog intact, a communication is established, in any way, between the two legs of the same frog;—3, that in the experiment by which we detect the current of the frog by the galvanometer, there is never in the wire of the instrument any other current save that which results from the sum of the two portions of the currents of the two limbs which are not discharged from limb to limb.

It is important to notice, that there is no necessary connection between nerves and muscles in the production of the proper current of the frog. Matteucci shows by several ingenious experiments, that, although in Galvani's and Nobili's observations, the nerve and muscle were brought in contact, or were made to form conspicuous parts of the arrangement employed in the development of the phenomena, the signs of the electric current are just as distinct when the circuit is completed by the contact of other parts; or if the continuity be maintained by muscles, the main nervous trunks having been removed. Thus, if a frog be flayed, and the bones and muscles of the pelvis be cut away, so as to leave the lower extremities attached to the thorax by the lumbar nerves, contractions will be produced by bending up the leg so as to bring it in contact with the eyes, the muscles of the head, or the back. And if this frog be placed with its head in one capsule and its legs in another, the current may be detected by the galvanometer in the ordinary way. Or, if the spinal nerves and the piece of the spinal cord be removed from the lower limbs prepared in the ordinary

way, the signs of the current may be obtained by the usual methods. Piles made of legs prepared in this way develop a current equally intense with that produced from piles with an equal number of elements composed of limbs with the nerves remaining. It thus appears that the electromotor element of the current is reduced to the muscles of the leg and thigh in organic union.

So far, indeed, is the nerve from contributing to the production of the electrical phenomena, that Matteucci found that a more feeble current was developed in piles formed of the legs of frogs in which a very long portion of the nerve formed an element. He prepared the legs, leaving attached to them the lumbar and crural parts of the nerve, and formed the pile by placing the nerve on the adjacent leg, so that the communication between the segments was maintained only by the nerves. And it may be shown further, that the nerve in these experiments acts only as a bad conductor of the electricity developed by the muscles; for, if the nerves be cut away, and the segments of the limbs connected by pieces of moist cotton instead, the phenomena of the pile continue unchanged.

Nothing analogous to the proper current has been found in any other reptiles but the Batrachian—nor in any other class of animals. It is not improbable, therefore, that the proper current of the frog may be due to some undiscovered peculiarity of structure in that animal.

How can we explain these remarkable electrical phenomena in the muscular current directed from the interior to the exterior of all muscles in all animals; and the proper current of the frog, directed from the feet to the head, and peculiar to the Batrachian reptiles?

It is not difficult to discover an explanation of the muscular current. The essential conditions necessary to develop the signs of this current are simply, that, by means of a conducting material, the interior of the muscular mass should be brought into communication with the exterior of the muscle, which is more or less tendinous, and covered with areolar tissue, and therefore different from the interior in structure and function. And as the signs of this current are apparent only whilst the muscle is living—that is, while it continues to display its contractile power, we may infer that the same organic conditions which are necessary to the development of contraction, are requisite for the development of electricity. Now all that is necessary for the development of the contractility of muscle is (as has been shown in Chap. vii.) a healthy nutrition, a due supply of arterial blood, and sufficient exercise of the organ. And it would be impossible, as Matteucci remarks, not to admit that the chemical action which must be going on throughout muscle, in the constant supply and waste of which it is the seat, can be unattended with the development of electricity.

In short, the organic actions of muscle, by which the electrical current is developed, may be compared to the inorganic phenomena attending its production from the decomposition of metals. When a plate of metal,* immersed in an acidulated fluid, is oxidized by the oxygen of the water, and then dissolved in the acid, we admit that an enormous quantity of electricity is developed during this action; we add, likewise, that, just as the two electrical states are disengaged, a synthesis takes place, and the effects of the previous decomposition are neutralized. It is only by means of certain arrangements, that we can obtain the free electricity which is developed during chemical action. We unite to the metallic plate, another which is not attacked by the water, and plunge this second plate also in the water. The circuit is thus established, and the electric current circulates in the liquid from the metal acted on to the other, and from this latter back again to the first through the metallic arc of union.

The metal acted upon in the artifical arrangement is represented, in the phenomenon of the muscular current, by the muscular fibre; the acidulated fluid is the arterial blood. The surface of the muscle, or any other conducting body not muscular fibre, but which is in contact with the muscle, represents the second plate of metal, which does not suffer chemical action, and which serves only to form the circuit. The direction of the muscular current is precisely such as it should be, supposing the current to be, as we have represented it, due to a chemical action taking place in the interior of the muscle.

The nervous system may act in two ways in connection with this phenomenon; 1, as an imperfect conductor, which makes part of a circuit, but is not the source of electricity; it represents the electrical state of the muscular mass, interior or surface, with which it is in connection; and 2, it acts in the conservation of the cause which disengages electricity, namely, nutrition. It is fully proved, that the integrity of the nervous system, and the nutrition of the muscles, are closely leagued together;

* Matteucci, loc. cit., p. 124.

it as it cannot be admitted that the chemical action which takes place in nutrition is mmediately arrested or suspended by the cutting off nervous influence, so we must low that the muscular current may continue after the nerve has ceased to exert any ontrol over the muscle.

The proper current of the frog does not admit of being explained upon these prin-ples. It has been supposed, as already stated, that this current is a thermo-electric e, due to the unequal cooling of nerve and muscle, depending on the difference of aporation in these two parts of the animal. But it has been shown that this cur-nt persists even after the removal of the nerve; and, moreover, as Matteucci re-arks, a current which is sensible to a galvanometer with a long coil, which traverses ick layers of liquid, which may be obtained by bringing muscle in contact with uscle, and which may be produced by holding animal parts in water, cannot, cer-inly, be of thermo-electric origin. It has also been supposed that this current is e to an electro-chemical action; that the leg of the frog is charged with alkali or lts, whilst the thigh or the lumbar nerve contains acid. But chemical analysis f these parts affords no countenance whatever to this hypothesis. There are markable points of analogy between this current and the muscular current. Mat-ucci's experiments have shown that the former has some marked connection with uscles, and with those of the leg more especially; and he has found that the same ircumstances which increase or diminish the muscular current, exert a similar in-uence upon the proper current. But they differ remarkably in point of duration; s the latter continues long after all traces of a muscular current has ceased to be iscoverable. It is highly probable, as before stated, that the true source of this cur-nt will be found in some anatomical peculiarity of the frog.

As in the ordinary phenomena of the nutrition of muscles, by which their state of assive contraction or tone is maintained, electricity is developed, it is most reasona-le to expect that during *active* contraction there should be a development of elec-icity, as there is of heat likewise, according to Becquerel and Breschet's observa-ons. This is shown by Matteucci in a very beautiful experiment which we have equently repeated with the same results. Place a prepared frog upon an insulating lane; then prepare the leg of another frog with the crural nerve dissected out and left ttached to the leg, the thigh being removed. Place the nerve of this leg upon one r both thighs of the other frog, and every time that those legs are excited to contract y a galvanic or a mechanical stimulus, contractions will be produced in the second g, which is connected with the first only by the contact of its nerve with the sur-ce of their muscles. The same effect will be produced, if the nerve of the frog's g be placed on the muscles of a warm-blooded animal,—a rabbit, for instance,— are being taken to remove any thick aponeurosis which may cover the latter.

If an insulating substance be placed between the muscles of the thigh and the nerve f the leg, no action will take place. The same effect is observed when gold-leaf is nterposed; but if the gold-leaf be torn, to however slight a degree, the leg will be rown into contraction.

The electricity developed during the contraction of the muscles, stimulates the erve which is laid upon them; the interposition of a non-conducting substance revents the electric discharge from reaching the nerve; and gold-leaf, being a better onductor than nerve, carries the electricity along it, passing by the nerve.

4. The study of the effects of electricity applied in various ways upon nerves has ed to some highly interesting and curious results.

Nobili ascertained that, in passing an electric current through the lumbar nerves f a frog, contractions occurred under different circumstances, according to the state f vitality of the nerves. He divided the vitality of the nerve into five periods, uring each of which different phenomena were produced by the passage of the cur-ent. In the first period, the *direct* current, or that directed from the brain to the erves, caused contractions in the muscles on closing the circuit; the *inverse* current, r that from the nerves to the brain, on opening it. In the second period, the *direct* urrent causes contractions on closing the circuit, and slight ones on opening it; the *nverse* current causes contractions only on opening the circuit. In the third period, ontractions occur only on closing the *direct* current and opening the *inverse*. In the ourth period, contractions occur only on closing the *direct* current; and in the fifth, e nerve ceases to be influenced by the electrical stimulus. Marianini, who subse-uently studied this subject, affirms that contractions take place only under two cir-umstances, namely, from the closure of the *direct* current, or from opening the *in-erse*; and that a sensation is caused by the *direct* current on opening, but by the *nverse* on closing.

Matteucci repeated these observations on the sciatic nerves of the rabbit, devoting ne nerve to the direct, the other to the inverse, current. On closing the *direct*

current, contractions were produced in the muscles of the limbs and back, with marked signs of pain; the same phenomena result from closing the *inverse* current, and from opening both. The signs of pain were greatest at the closure of the *inverse* current, and the contractions were most at the closure of the *direct* current. The commencement and the interruption of an electric current of a certain intensity, acting upon a certain portion of the nervous system, are followed by the same phenomena, whatever be the direction of this current in the nerve. After some time, which is shorter as the current is more intense, the phenomena take place in a different manner. Upon interrupting the direct current, the contractions of the muscles of the limbs are feeble, but there are signs of pain, and the muscles of the back are contracted; but, when the direct current is closed, the effects are limited to contractions of the posterior limbs. When the inverse current is used, contractions of the muscles of the back and signs of pain occur on closing it, while the contractions of the limbs are slight; but, on the interruption of it, contractions of the limbs alone take place.

The following tabular view will exhibit these latter results more clearly.

Direct current . . .	closing . . .	contractions in muscles of posterior limbs.
	opening . . .	marked signs of pain, and contraction of muscles of the back. feeble contractions of posterior limbs.
Inverse current . . .	closing . . .	signs of pain, contractions of muscles of back, and feeble ones of the posterior limbs.
	opening . . .	contractions of the posterior limbs.

So that, after the lapse of a little time, the phenomena produced by closing the inverse current, become precisely the same as those on opening the direct, and *vice versâ*.

The contractions of the muscles of the back, which are supplied from nerves which come off above the point of excitation, are due to the irritation of the nervous centre, affected through sensitive nerves; for these contractions cannot be produced if the portion of the cord from which the nerves arise have been removed.

After the nerve has been exhausted, so as to yield the phenomena of the second period, as shown in the table, it may be excited to act as at first, either by increasing the intensity of the current, or by exciting points of the nerve nearer its peripheral extremities.

A simple experiment illustrates the different effects of the direct and inverse current in a very striking manner. The limbs of a frog are prepared according to the ordinary method of Galvani. If a current be passed from one side to the other through the lumbar nerves, it is plain that it will be direct in the nerves of one side, and inverse in those of the other side. During the first period, there are contractions both on completing and interrupting the circuit; but in the second period, one limb contracts on opening, the other on closing, so that the limbs are made to kick alternately, that which is traversed by the direct current on closing, and that by the inverse current on opening.

It is impossible to observe these curious phenomena, whether of the muscular current, or of the effects of electricity on nerves, without perceiving how utterly inexplicable they are by the electrical theory of nervous power, or, indeed, how much opposed they are to such a view. They serve, in the most remarkable manner, to confirm the views which we have advocated in a former chapter, which regard the nervous power as a polar force developed by molecular changes in nerves excited by various stimuli, of which, next to the mental, that of electricity is the most powerful.

We have already (p. 223) given the general results of Professor Matteucci's very interesting series of experiments on the torpedo. We shall content ourselves, now, with remarking that he has succeeded in illustrating very strikingly the marked analogy between the actions of the electrical organ and those of muscle, and the relation which each bears to the nervous system. Both are organized to act in a particular way: the one to develop electricity without any visible change in itself; the other to contract, with a demonstrable evolution of both heat and electricity. Both will manifest their peculiar phenomena by direct irritation, or by indirect irritation through the nerves. Both are brought under the control of the will by the nerves; the section of which paralyzes the influence of the will over both, but does not destroy the peculiar power of either. In the electrical fish, irritation of the electrical lobe of the

rain is capable of exciting a discharge of the organ; just as irritation of a segment f the spinal cord causes contraction of the muscles supplied by it. A current of lectricity transmitted through the electrical organ or its nerves, causes discharge; nd a similar current sent through a muscle or its nerves, causes it to contract. All ıe circumstances which modify the nutrition of muscle, will similarly affect that of ıe electrical organ.*

CHAPTER XII.

ON SYMPATHY AND SYMPATHETIC SENSATIONS AND MOTIONS.

It is popularly known that the act of yawning, performed by one ndividual in a company, is apt to induce in many of the others an rresistible tendency to the same act. In a similar manner, the ex- :itement of certain emotions (mirth or sadness, laughter or tears) is ıpt to spread through an assemblage of persons with extraordinary apidity. The power of eloquence, of music, or of spectacle, to pro- luce such effects, is witnessed every day in places of public resort, whether for devotion, business, or amusement.

Many instances are known in which convulsions have been ex- :ited in persons not previously subject to them, by the sight of a patient in an epileptic fit. And peculiar nervous disorders, of a con- vulsive kind, have been found to affect nearly all the members of a :ommunity, without the slightest evidence of their being contagious ›r infectious. An impression upon an organ of sense may produce :ffects very different in their nature to anything which could be anti- :ipated; and these may be purely of a physical kind, or they may ıct primarily upon the mind. Thus certain odours will induce syn- :ope in some people; and the smell of a savoury dish to a hungry ›erson, or even the mention or the thought of a meal, will excite a low of saliva. The emotion of pity excited by the sight of some ›bject of compassion, or by a narrative of a mournful kind, will pro- luce a copious flow of tears.

All such phenomena are said to result from Sympathy. When ›ne yawns, immediately in consequence of another's yawning, the ormer evidently and truly sympathises with the latter; and the :onvulsions which are induced by the sight of another in a fit, are ıot less sympathetic. The individual in whom the convulsions are nduced sympathizes with the other. Such obvious instances of ympathy between different individuals led to the supposition of ome such similar consent between different or even distant parts in he same person.

Motions or sensations caused in certain parts in consequence of a ›rimary irritation of other and distant parts are of the sympathetic :ind. These motions or sensations are produced in, as it were, an

* Traité des phénomènes électro-physiologiques des animaux, par C. Matteucci; suivi 'études anatomiques sur le système nerveux et sur l'organe électrique de la Torpille, par aul Savi. Par. 1844.

indirect or circuitous manner, or one different from that in which they are ordinarily excited.

Thus a stimulus to the olfactory membrane causes a peculiar affection of the sense of smell, and thus occasions that depression of the heart's action from which results a state of syncope. Or, another affection of the same sense causes a suddenly increased action of the salivary glands.

If we analyze any one of these examples of sympathetic actions, it will appear that three circumstances are to be noticed in the production of the phenomena: 1st, the primary exciting cause, which may be an object presented to the mind through one of the organs of sense, or causing an impression upon any sensitive nerve, and therefore upon some part of the centre of sensation; 2dly, the part affected directly by this primary stimulus; and, 3dly, the action or sensation resulting from the affection of this part.

Many other sensations or motions may be enumerated besides those above referred to, whether occurring in health or in disease; and we shall give examples of these before we discuss this subject further.

The examples of sympathetic *sensations* which may be adduced are chiefly of the morbid kind. Pain is felt at a certain part, in consequence of an irritation in another part distant from it, and apparently altogether unconnected with it. One of the most familiar of these is pain in the knee from disease of the hip-joint. So marked in some instances is the pain in the knee, and so much has it absorbed the patient's attention, that the real seat of the disease has been overlooked, and the remedies been applied exclusively to the knee. Pain in the right shoulder from disease of the liver is a sympathetic sensation of similar kind; and sometimes the hepatic irritation causes pain over a more extensive surface. Whytt mentions, that, in two cases of suppuration of the liver, he had seen the patients "affected with a numbness and debility of the right arm, thigh, and leg." The peculiar sensations felt in the teeth from a noise which grates upon the ears, is sympathetic of the irritation of the auditory nerve. Practitioners are well aware how many morbid sensations in parts remote from the intestinal canal may be cured by the removal of scybala or other accumulations from it. Painful affections of the nerves of the face, and of other parts, are often due to a cause of this kind. The irritation of a stone in the bladder gives rise to pains in the thighs, or to itching at the end of the penis; and uterine irritation, whether from disease or from the enlargement of that organ in connection with the early stage of pregnancy, causes similar pains in the nerves of the thighs.

Headache and defective vision are frequently produced by disordered stomach. A draught of very cold water, or ice, taken quickly into the stomach, may occasion acute pain in the course of either frontal nerve. This same nerve on one side is frequently the seat of pain after the imprudent use of acid wine or other fermented liquors.

Movements, excited by the operation of a stimulus applied at a distance, form a large proportion of the instances of sympathetic

phenomena. All the ordinary physical nervous actions in which motions are excited by stimulating a sentient surface, may be regarded as examples of sympathetic actions.* The contraction of the iris upon the application of the stimulus of light to the retina, or of the pharyngeal muscles by stimulating the mucous membrane of the fauces, are instances in point, where the stimulus acts indirectly upon the contracting fibre. Nothing is more sure than that in these instances the change wrought by the stimulus in certain sentient nerves travels by a circuitous route through a nervous centre to the muscles which are called into action. Akin to these actions are the forcible respiratory movements which may be excited by irritation of the tracheal membrane, as coughing; or sneezing, by stimulating the nasal membrane; or vomiting, by irritating the fauces. Spasmodic affections are often instances of morbid actions in sympathy with intestinal irritation, or the irritation of teething in children. Partial or general convulsions are very frequently due to either or both these causes. We have known the most violent opisthotonos co-existing for a considerable time with the presence of lumbrici in the intestine; but ceasing immediately on the removal of the worms. Vomiting is commonly sympathetic of diseased kidney, or of the passage of a calculus along the ureter; or it may be induced by the introduction of a catheter into the urethra. Irritation of the intestines, as in cholera, causes cramps of the most violent kind in the lower extremities and abdominal muscles. The contractions of the abdominal muscles in parturition, although materially aided by the will, are in consent with the expulsive efforts of the uterus.

The consentaneous action of symmetrical parts is no doubt due to a similar cause to that by which most of the sympathetic actions are excited, and more especially in those parts where symmetry of action is constant, although liable to be interrupted by the influence of the will.

A distinct class of sympathetic actions consists of those in which certain parts enlarge or become developed simultaneously with, and to a certain extent in effect of, the increase of others. The penis, the beard, the vocal organs, experience a marked increase of development at the adult period of life simultaneously with the enlargement of the testes; and, it may be added, in effect of their increase, because the early removal of these organs prevents the growth of the others. And so likewise as the ovaria are developed, the uterus, the vulva, the mammæ, increase in size; the ovarian and uterine irritation which accompanies the menstrual flux causes enlargement of the breasts, which subsides as soon as that period has gone by.

The various examples enumerated in the preceding paragraphs may be classed under three heads: first, sympathies between different individuals; secondly, those which affect the mind, and, through it,

* It has been remarked, that the term "sympathetic *actions*" involves a contradiction. But it may be observed, that the contraction of the muscles, on which the action depends, is only the natural mode in which that class of vital organs can manifest their consent with certain states of nervous centres, or of sensitive nerves. The action is the result of the state which the muscle assumes in sympathy with the stimulated nerve. The contradiction is therefore apparent, not real.

the body; and, thirdly, those which are strictly organic, and therefore physical.

Of the first class of sympathies we can offer no physical explanation. Whether the nervous system of one individual can directly affect that of another, or whether the effect is produced on the imagination, and afterwards on the nervous system, are questions still *sub judice*. The serpent fascinates his prey, apparently by the power of his eyes, and it is well known that one man can exert a marked control over another by a mere look; and in the same way man can control other animals, even the fiercest carnivora, by a firm and decided glance of the eyes. It is no explanation of sympathetic phenomena of this kind to ascribe them to the effect of a tendency to imitation. Imitation is voluntary; these actions are involuntary, or take place even in despite of the will. (*Bostock's Physiology*, vol. iii., p. 227.)

In the second class of sympathetic phenomena, an affection of the mind is a necessary link. But why that affection of the mind should produce its peculiar effect is a question of difficult solution. Why should the perception of certain odours produce in one case increased action of the salivary glands, and in the other case cause syncope? The only reply which can be made to this question is, that in these instances the impression on the sensorium causes a change there analogous to that which an original affection of the mind of similar kind would produce, and therefore gives rise to effects of the same nature as those resulting from that mental change. Thus the smell of savoury food excites in the mind the idea of food, which in a hungry man would, if it occurred spontaneously, occasion a flow of saliva. And the odour which occasions syncope, creates in the mind an emotion of disgust, which, if it arose independently of the physical impression, would affect the heart through the centre of emotion. It is plain, however, that that portion of the nervous centre which is affected in such cases, must have a direct influence upon the parts in which the sympathetic phenomena appear; and this through commissural fibres, or the continuity of its gray matter with that of the centre from which its nerves immediately spring; thus, in the instances referred to, the centre of sensation, which is first affected, is, through the medulla oblongata, connected with the salivary glands by the fifth nerve, and with the heart by the vagus.

We derive an explanation of the third class of sympathetic phenomena from the known laws of sensitive and motor nerves. It is known that stimulation of a sensitive nerve at its origin, or in any part of its course, will give rise to a sensation which will be referred to the peripheral extremity of the stimulated fibres; and that a stimulus applied to a motor nerve causes a change in it which spreads peripherad from the point stimulated, and therefore affects the muscular parts with which it is connected. It is known, also, that a sentient nerve may excite a motor or sensitive nerve which is implanted near to it in the nervous centre—doubtless through the change which it produces in that centre; nor can it be doubted that a sensitive nerve may receive such a powerful stimulus as to exalt the polar force of

large portion of the nervous centre in the neighbourhood of its sertion, and thus to excite a similar change in all the nerves, iether motor or sensitive, which are connected with it. Thus, cording to the intensity of the original stimulus, there will be a diation of nervous force from the centre, either in one or two otor or sensitive nerves, or in several such; and the number and riety of the sympathetic phenomena will thus depend on the in- nsity and extent of the change in the nervous centre excited by the imary stimulus.

To explain then the phenomena of sensation and motion under nsideration, we must determine the individual nerves affected in ch instance, and ascertain what connections they have with each her. We learn from anatomical investigation, that, although nerves nastomose with each other in their distribution, this anastomosis is y no means of that kind which would justify the supposition that n irritation could be communicated from one to the other in their ourse. The nerve-fibres only lie in juxtaposition, but do not com- nunicate: and there is an evident provision in the tubular membrane nd white substance of Schwann for the insulation of the central xis, which is probably the effective substance in the nervous action. We must seek, therefore, in the nervous centres for such a communi- ation between these nerves as may explain the excitability of one by he other. In the present state of our knowledge we can do no more han state it as in the highest degree probable that nerves implanted n the centre immediately contiguous to each other can exert an influ- nce upon the vesicular matter of the centre, and upon each other.

But there are certain facts which demonstrate beyond all doubt, hat, in such actions as we refer to, the integrity of the centre forms necessary condition. First, in many of the instances, it is plain that here can be no connection between the affected nerves elsewhere han in the centre, for they are so distinct from each other that there not even that apparent connection which results from the anasto- osis of a fasciculus of fibres of the one with a portion of the other. econdly, the removal of the portion of the nervous centre with hich any one of the nerves concerned in the sympathetic action is nnected, will prevent the development of the phenomenon, al- ough the nerves themselves remain uninjured in their peripheral stribution, or in their connection with each other. Thirdly, if there re any peripheral communication between nerves, it would be st likely to take place in the plexuses. Experiments, however, on the nerves which lead to these show that each nerve-tube, in its ssage through them, retains its isolation as distinctly as in any other rt of its course. The three nerves which supply the lower ex- mity in the frog, says Müller, form a plexus from which two nervous nks issue: if one of these latter be divided and isolated from all connections with muscles, and the portion of it connected with the xus irritated, the impression will be transmitted in the centripetal ection by the sensitive fibres of the nerve; but the motor fibres of other nerve arising from the plexus are not affected, and excite

no contractions in the muscles to which they are distributed. (*Baly's Müller*, vol. i. p. 756.)

In applying these principles to the explanation of the instances which we have quoted, we shall find it difficult to determine the central connection in some, although in others such a connection is highly probable. It remains, therefore, for future anatomical research to ascertain what that connection is which enables one nerve to sympathize with another. In the instance of pain in the shoulder in sympathy with irritation of the liver, the hepatic irritation excites a change in some sensitive nerves, which is propagated to the centre, and there affects some of the sentient fibres distributed in the region of the shoulder. The phrenic and the external thoracic nerves are both or either of them, but more especially the former, favourably situated to constitute the excitant of such a sympathetic sensation. The phrenic nerve of the right side is largely distributed upon the peritoneal surface of the diaphragm, and upon the inferior vena cava, and forms many connections with the hepatic plexus in the substance of the liver. It may therefore readily participate in any irritation of that organ. Now the phrenic nerve is implanted in the spinal cord on a level with the third or fourth cervical nerves; and the nerves of the shoulder form their connection with this central organ about the same level. The origins of these nerves are sufficiently contiguous to each other to warrant the belief that an irritated state of one may be propagated to the other through the vesicular matter of the centre. But it may be inquired why the irritation is limited to sensitive nerves of the shoulder; and why movements are not excited by the stimulation of the motor fibres of the phrenic itself, or of other nerves? The limitation of the irritation to one or two nerves depends on the degree of the stimulus, and the absence of movements is due to the disposition of the phrenic on the surface being unfavourable for the excitation of motions by irritation of its peripheral branches (see page 298). And the experiment cited from Müller, in the last paragraph, shows that simple irritation of the *trunk* of a compound nerve in connection with the centre is not sufficient to produce motion; which requires probably either a more prolonged and violent irritation of the nerve, or a polar state of the centre in which it is implanted.

Some of the instances of sympathetic sensations, referred to above, do not admit of an explanation so obvious. The pain over the brow, from ice or cold water in the stomach, may be referred to irritation of the gastric branches of the vagus, communicated in the medulla oblongata to the fifth; but why the irritation should be limited to the ophthalmic division of the fifth, cannot be accounted for in the present state of our knowledge.

In those sympathetic movements which are of ordinary and normal occurrence, two provisions seem to be secured, namely, a certain peripheral organization of the excitor nerve, and a certain central relation between it and the motor nerve. But in those which are of a morbid kind, it is necessary to suppose the existence of a more or less exalted polarity of the centre, in order to explain the phenomena

ully. This polar state will continue, in many instances, even after he primary peripheral irritation has been removed, as in tetanus, or n the convulsions from intestinal irritation; and we learn from this act the importance in practice of attending to the state of the nervous centre, as well as to the removal of the irritating cause.

There are other sympathetic phenomena, of the physical kind, in which, however, the nervous system does not appear to take a prominent part. Such are the changes which occur in different and listant organs in connection with a particular period of life, or the levelopment of a particular function. Among these, are the phenomena of puberty in both sexes; the enlargement of the mammæ in pregnancy. Whatever part the nervous system may take in such changes, it is impossible to account for them by reference to that system only; they must rather be regarded as phenomena of nutrition occurring in harmony with the laws of growth, and therefore affecting the vital fluid more particularly than any part of the system of solid parts.

Continuity of texture disposes, as is well known, to the extension of a diseased state originating at some one point. So also does *contiguity*. Phlegmonous inflammation of the areolar tissue, and erysipelas in the skin, spread with great rapidity. Inflammation arising in one of the opposed surfaces of a serous membrane, readily attacks the other. These effects have been vaguely assigned to sympathy, (the *continuous* and *contiguous* sympathy of Hunter.) But it cannot be supposed, that the nervous system takes part in the production of such phenomena, which ought rather to be ascribed, in the one case, to the continuity of blood-vessels,—and, in the other, to contamination either by effused fluids or by morbid blood.

On the subjects referred to in this chapter, consult Whytt on the Sympathy of the Nerves, an admirable exposition of the phenomena, obscured, however, by his erroneous views respecting the all-pervading influence of the mind upon vital phenomena;—Hunter on the Blood, &c.;—Alison on the Physiological Principle of Sympathy, Edin. Med. Chir. Trans., vol. ii.;—Müller's Physiology.

CHAPTER XIII.

OF THE PACINIAN CORPUSCLES OF THE NERVES.

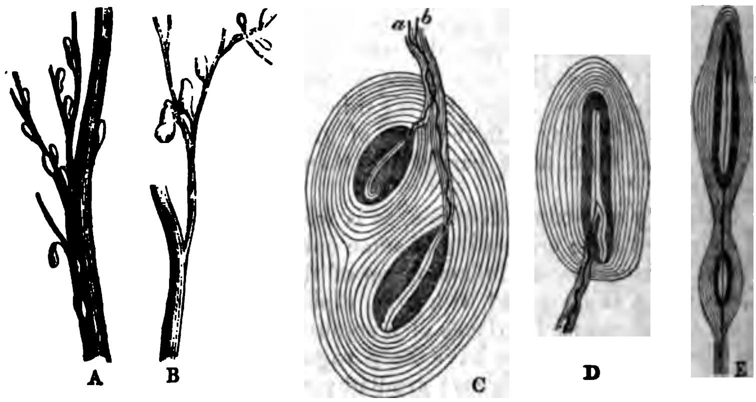
We propose to give in this chapter an account of certain very remarkable structures, appended to the nerves, to which attention has only very recently been drawn in this country.* These are the Pacinian corpuscles, so named by Henle and Kölliker† from their

* Brit. and For. Med. Rev., Jan. 1845.

† Ueber die Pacinischen Körperchen an den Nerven des Menschen und der Säugethiere. Zurich, 1844.

discoverer, Pacini.* In the human subject they are found in great numbers, in connection with the nerves of the hand and foot, the nerves, as it may be presumed, of touch; but they also exist sparingly on other spinal nerves, and on the plexuses of the sympathetic, though never on the nerves of motion. In the mesentery of most cats they are very readily seen by the naked eye, (usually in considerable numbers,) as pellucid, oval grains, rather smaller than hemp-seeds, and they are here very favourably situated for examination.

Fig. 74.



A. Nerve from the finger, natural size: showing the Pacinian corpuscles.
B. Ditto, magnified 2 diam.; showing their different size and shape.
C. Unusual form, from the mesentery of the cat; showing two included in a common envelop:—a. b. are the two nerve-tubes belonging to them.
D. Another, from the same: showing an offset from the central cavity, containing a branch of the pale nerve.
E. Rare form, from the mesentery of the cat (reduced from Henle and Kölliker): showing two corpuscles placed in succession on a single stalk, and furnished with the same nerve-tube, which resumes its white substance in the interval between them.

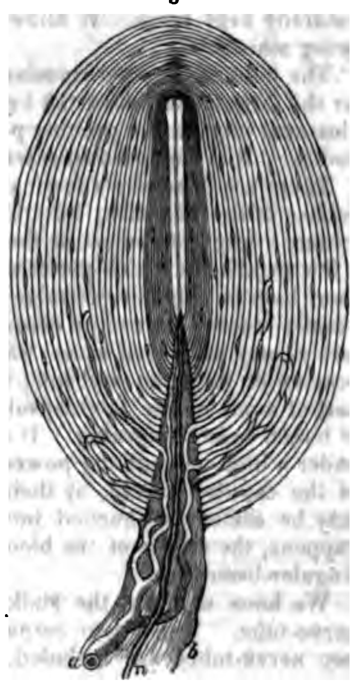
Fig. 74, A, B, will give a correct idea of their relation to the nerves in the palm and sole. They are especially numerous on the smaller twigs, to which they are generally placed parallel, though frequently at an acute, and sometimes at an obtuse angle. They are more or less oval, often elongated and bent; sufficiently tough to resist moderate pressure, and nearly transparent, with a whitish line traversing their axis. They lie imbedded in the areolar tissue, and adhere to it by their outer surface. They always present a *proximal end*, attached to the nerve by a *stalk* of fibrous tissue, prolonged from the neurilemma, and occasionally $\frac{1}{10}$ of an inch long; and a *distal end*, lying free in the areolar tissue. The corpuscles in the human subject have an average length of from $\frac{1}{20}$ to $\frac{1}{10}$ of an inch.

* Pacini first noticed them in 1830, and subsequently in 1835; and in 1840 gave an account of them (Nuovi organi scoperti del corpo umano dal Dott Fillippo Pacini. Pistoja, 1840), which has been rendered much more accurate and complete in its details by Henle and Kölliker. Coming to the investigation of these corpuscles with the knowledge of what these eminent anatomists had accomplished, we have confirmed their results by numerous observations, from which the account about to be given has been principally taken. A. G. Andral, Camus, and Lacroix had announced their existence at a *concours* in Paris in 1833, but do not appear to have apprehended their real nature.

nute examination of these singular bodies discloses an internal re of a highly interesting kind. They consist, first, of a series ibranous capsules, from thirty to sixty or more in number, en- one within the other; and, secondly, of a single nervous fibre, :ubular kind enclosed in the stalk, and advancing to the central :, which it traverses from end to end.

eference to the accompanying figure (75), which exhibits the structure, the ten or fifteen innermost capsules may be ob- to be in contact with one another, while the rest are separated :ar space containing fluid. This is almost constantly observed, the specimen has been allowed to imbibe water sufficient to the inner capsules from each other; and hence these have istinguished from the rest as em *of internal capsules*. The psular spaces between the vary in width, especially ressure, and sometimes we en some of the outer capsules contact. The capsules are d there united by connecting of similar structure, passing rsely or obliquely across the the spaces do not commu- if some of the outer capsules ctured, their fluid escapes; se within remain distended. le puncture down to the :ries of capsules causes all d to escape, and the whole pse; and again, the capsules often peeled off in succes- owing their union to be but In fact, except by the few already mentioned, they are only along the stalk, and for ble extent at the opposite he stalk seems to be inserted kind of conical tube, which tes all the capsules in suc- but has its proper wall, so to communicate with the sular spaces. This wall s the capsules, and the tissue of the stalk is gradu- ited with its inner surface s the central capsule, where nates. There is generally a nion between a variable number of the capsules, as we trace m the opposite end of the central capsule towards the surface B, o); this was called by Pacini *the intercapsular ligament*.

Fig. 75.



Pacinian corpuscle, from the mesentery of a cat; intended to show the general construction of these bodies. The stalk and body, the outer and the inner system of capsules, with the central cavity, are seen. *a.* Arterial twig, ending in capillaries, which form loops in some of the intercapsular spaces, and one penetrates to the central capsule. *b.* The fibrous tissue of the stalk prolonged from the neurilemma. *n.* Nerve-tube advancing to the central capsule, there losing its white substance, and stretching along the axis to the opposite end, where it is fixed by a tubercular enlargement.

We do not, with Henle and Kölliker, deny its existence, but have seldom seen it reach the surface of the corpuscle.

The wall of the capsules of the external system often appears to consist of two laminæ. The inner of these contains, at intervals, flattish, oval nuclei projecting inwards (fig. 76, A, d). The outer is sometimes seen, as if in section, by a series of dots, representing transverse or circular fibres. The capsules always exhibit a decided transverse fibrillation, which in a great measure disappears on the addition of acetic acid, showing the almost complete absence of the yellow fibrous tissue. The outermost capsule of all, however, is invested with the network of this, as well as of the white fibrous element of the areolar tissue. The internal capsules do not show the double wall, but they contain nuclei.

The capsules seem to be over-distended by their fluid, so as to be naturally kept tense. If allowed to dry, they do not fill again on being moistened.

The fluid of the intercapsular spaces is so abundant as to constitute far the largest portion of the bulk of the entire corpuscle, and by its clearness imparts the peculiar pellucid lustre so characteristic of these bodies. It is supposed to resemble the serum of the blood.

There are generally a few capillary blood-vessels ranging over the surface of the capsules; but the corpuscles are chiefly supplied by a minute artery that enters in the fibrous tissue of the stalk, sends off a few capillaries which perforate the tubular canal, and form each a short loop in the intercapsular spaces (fig. 75): one capillary vessel usually reaches the central capsule (fig. 76, A), and sometimes, though rarely, may be traced some way along its wall. In the larger corpuscles of the palm and sole, the capillaries penetrate to the distal part of some of the intercapsular spaces, and may there form a kind of bunch before returning. If a quite recent specimen be examined, under a high magnifying power, the blood-globules are often visible in the capillaries, and, by their swelling on the addition of water, may be sometimes hurried into a sort of circulation. When this happens, the course of the blood in the corpuscles is displayed with singular beauty.

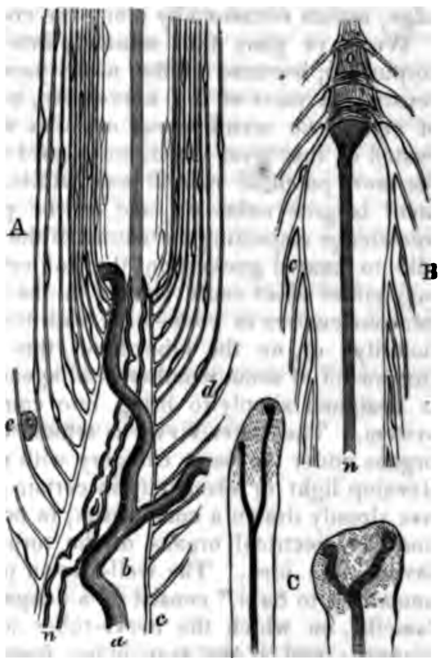
We have said that the stalk of every corpuscle contains a single nerve-tube. When two corpuscles are seated on a common stalk, two nerve-tubes are included, one of which belongs to each (fig. 74, c).

The nerve-tube is proportioned in size to that of the corpuscle, that is, to the number of capsules composing it. Even when smallest, it is conspicuous enough, if the specimen be recent; for it is invariably furnished with the white substance of Schwann, and displays the double contour. When largest, it equals any found in the body. It is very liable to present varicosities, and its course in the stalk is more or less undulating.

On entering the innermost capsule, the nerve-tube suddenly loses its envelop of white substance and becomes pale; the axis-cylinder alone remaining, perhaps still invested by the tubular membrane (see p. 194). Thus reduced in size and rendered pale, the nerve stretches

ow along the very centre of the capsular cavity to the ıd, where it swells into a knob, or button, which fixes : inner surface of the capsule. In this swelling nothing eted beyond the pale, faintly fibrous character of the axis-No nucleus, like caudate nerve-ın be seen.—the axis-cylin-near its termi-:wo or even into ches, each of .nates by an ad-llen extremity. this division oc-e proximal end ·al capsule, and branches passes ıde course into :e offset from the ity, and there fig. 74, D). In f these varieties s constant, viz., rable accuracy the pale nerve path in the axis ity, everywhere from the walls. t apparent when bent upon itself, might be imag-ıe nerve would the centre to-oncavity of the : keeps a central as well as else-is, perhaps, may the nature of s of the central ıediately envel-ıle nerve. Near the cavity an of soft, delicate,

Fig. 76.



A. Termination of the stalk, and commencement of the central cavity. *n.* Nerve-tube advancing to the central capsule, and there suddenly losing its white substance and becoming pale. *a.* Artery ending in capillaries: one of which enters an intercapsular space, the other advances with the nerve into the inner capsule. *b.* Conical tube which receives the stalk: the fibrous tissue of the stalk is not represented. *c.* Wall of this tube, continuous with the successive capsules, here seen in section. *d.* Corpuscle of the capsular wall. *e* More spherical granular corpuscle, of which a few only exist.

B. Distal end of the central cavity. *n.* Pale nerve advancing along the axis, to be fixed by a swollen part at the further end. *c.* Wall of the central cavity, receiving the insertion of some of the neighbouring capsules, here a little separated from each other by water. *o.* Intercapsular ligament of Pacini, continued a little way towards the surface.

C. Two varieties of bifid extremity of nerve, attached to the distal extremity of the central cavity.—All magnified 320 diam.

fibres, with elongated nuclei, is often visible (fig. 76, A); h the space immediately surrounding the nerve is quite we are disposed to consider the substance occupying it solid to keep the nerve in its place. It does not seem to d, like that distending the intercapsular spaces.

d Kölliker have remarked, that, where two corpuscles are ccession on a single stalk (fig. 74, E), the pale axis-cylin-

der regains its envelop of white substance from its point of leaving the central cavity of the first, to its entering that of the second; and that in some cases, where the central cavity is bent suddenly upon itself, so that it cannot be fairly surrounded by capsules at the bend, it is there provided for a little way with white substance. A very delicate layer of the same substance, just thick enough to give a dark edge, occurs occasionally along the course of the pale fibre.

We have gone thus minutely into the structure of the Pacinian corpuscles, because of the novel aspect in which they present the constituent parts of the nerve-tube, placed in the heart of a system of concentric membranous capsules with intervening fluid, and divested of that layer which we regard as an isolator and protector of the more potential central axis within. The object of this arrangement is quite unknown, and in the present uncertain state of our knowledge respecting the nature of the nervous force, it seems almost idle to hazard guesses on the subject. The apparatus of lamellæ may either effect some change in the enclosed nerve, by which the nervous centres in connection with it may be influenced as to their polarity; or, on the other hand, this apparatus may be the special instrument of some peculiar vital agency, which the nervous filament is designed simply to bring into communication with the nervous system. The latter view, to which we incline, would bring these organs under the same category with muscles, and the organs which develop light or electricity in certain of the lower animals. Pacini has already drawn a comparison, in point of structure, between them and the electrical organs of the torpedo; and Henle and Kölliker favour this idea. The well-known prisms of the electrical organs, according to Savi,* consist of a congeries of very delicate transverse lamellæ, on which the nerve-tubes are distributed in a plexiform manner; and, if we may judge from his figure, this plexus is not resolvable into loops, but consists of true inosculations of the ultimate tubes, which also retain the white substance of Schwann: but further researches are greatly needed on this point. Wagner, with more probability, describes the nerves to terminate on the lamellæ in the same looplike manner as in striped muscle.† These lamellæ are separated by fluid, and only adhere through the medium of the wall of the prism. If this be the true history of this structure, it appears to establish some general analogy between the electrical organs and the corpuscles; but how far this can be shown to hold in essential characters, especially in the mode of termination of the nerves, and their arrangement with regard to the membranes and fluid, is still a matter of doubt. Meanwhile we deem it most prudent to forbear from speculating concerning the office of the Pacinian corpuscles.

Having thus far completed the physiological anatomy and physiology of nerves in general and nervous centres, we proceed next

* Paul Savi, in Matteucci, loc. cit.

† Comparative Anat., translated by Tulk.

others, we prefer to consider these particular fibres along other nerves of pure sense, namely, the olfactory, the optic, auditory. As the peculiar function of these nerves depends eir peripheral organization, as well as on their central con- their physiological anatomy involves necessarily that of the f sense. We shall commence with the most simple, namely, ınd Taste, and afterwards proceed to Smell, Vision, and

econd class of nerves contains the third, fourth, sixth, portio he seventh, and the ninth pairs of nerves according to Willis's ıent, all of which are motor in function.

third class we place the fifth and eighth pairs of nerves, and ıl nerves.

', we shall examine the Sympathetic nerve.

CHAPTER XIV.

REMARKS ON SENSATION.—OF THE SPECIAL SENSES.—OF THE : OF TOUCH.—ANATOMY OF THE SKIN, AND ITS APPENDAGES.

TION is an affection of the mind occasioned by an impression ı certain parts of the nervous system, hence called sensitive. of the sensitive organs, and a corresponding perception by l, must concur to produce sensation: either condition may ne, but then the phenomenon is not a true sensation, in the ion here given to the word. Thus, light falling on the eye excites the whole visual sensitive apparatus, while the organ ption is inactive: on the other hand, in dreams, vivid pictures ts float before the mind, and are referred by it to the external

their ill-defined limits. The peripheral parts are more conspicuously placed, and on several accounts are commonly styled, *par excellence*, the organs of sensation: they are specially adapted to receive in the most advantageous manner the impressions to which their excitability is adapted to respond. The intervening nerves are, more properly speaking, media of transmission.

Sensations excited by a stimulus originating in the body itself, especially if it act rather on the intermediate or central part of the sensitive apparatus than on the peripheral, are termed *subjective*; on the other hand, they are styled *objective* if the stimulus be derived from without.

Under the name of *common* or *general sensibility* may be included a variety of internal sensations, ministering for the most part to the organic functions and to the conservation of the body. Most parts of the frame have their several feelings of comfort and pleasure, of discomfort and pain. In many of the more deeply seated organs no strong sensation is ever excited, except in the form of pain, as a warning of an unnatural condition. The internal sensations of warmth and chillness, of hunger, thirst, and their opposites, of nausea, of repletion of the alimentary and genito-urinary organs, and of the relief succeeding their evacuation, of the privation of air, &c., with the bodily feelings attending strongly excited passions and emotions, may be mentioned among the principal varieties of common sensation.

The *special* sensations are referable to five leading forms, and are distinguished not less by their several modes or characters, than by the more special and elaborate construction of the peripheral parts of their respective organs, whereby these are adapted to receive the impressions of their appropriate stimuli. The special sensations excited through the instrumentality of the peripheral organs of *touch*, *taste*, *smell*, *vision*, and *hearing*, are primarily designed to inform the mind of the conditions of the external world; and it is for the most part only in a secondary manner, or through the mind, that they operate on the organic functions, or for the construction of the body.

Almost all sensation is attended with the idea of locality, the mind referring the cause of the change it experiences to the peripheral part of the sensitive apparatus excited. Thus the ideas of distance, extent, and relative position originate in the very construction of our bodies, and soon become applied to the material objects around us by the comparison of the impressions on our different organs, and their several parts, with one another. The abstract idea of space is a further conception of the mind.

OF TOUCH.

This is the simplest and most rudimentary of all the special senses, and may be considered as an exalted form of common sensation, from which it rises, by imperceptible gradations, to its state of highest development in some particular parts. It has its seat in the whole of the skin, and in certain mucous membranes, as that of the mouth,

l is therefore the sense most generally diffused over the body. It also that which exists most extensively in the animal kingdom; ing, probably, never absent in any species. It is, besides, the diest called into operation, and the least complicated in its im-essions and mechanism. On these accounts it will be the first ated of.

The nerves of touch are the same, or at least are derived from the me part of the cerebro-spinal centre as those of common sensation. hey are the posterior roots of the spinal nerves, and some fibres of e eighth and fifth encephalic nerves. The peripheral organ of touch which they are distributed is a tissue everywhere diffused over the tient surface, but which in most situations is elevated into papillæ ore or less distinct from one another, and closely set, according to e tactile power. The nerves of touch are remarkable for the nglia which are formed upon them on their emergence from the rtebral canal, and for the subsequent admixture with most of them f nerves of motion. In these respects they differ from those of the ther special senses, except taste, which ranks next to touch in the cending scale.

In accordance with our general plan, we shall commence with an atomical description of the skin, which is the principal seat of uch; and it will be convenient to include with it an account of the rious glands and appendages found in connection with this organ, hether they have any relation to the sense in question or not. We ust premise, however, that this external integument is a part only a great physiological system, which comprehends also the mucous embranes, and the true or secreting glands; all of which, taken gether, and reduced to their most simple expression, are a continuous embrane, more or less involuted, more or less modified in the mentary tissue which compose it or are in connection with it, and thin which all the rest of the animal is contained. This expanse nsists of two elements; a *basement tissue* composed of simple mem-ane, uninterrupted, homogeneous, and transparent, covered by an *ithelium*, or pavement, of nucleated particles. Underneath the sement membrane vessels, nerves, and areolar tissue are placed . 62).

The sense of touch exists only in those regions of this great sys-m which are exposed to the contact of foreign bodies, and where is essential to the comfort or preservation of the animal that the esence and qualities of external objects should be perceived. ese regions, however, demand a greater protection, for the same ason; and hence it happens that the development of this sense found to be generally accompanied with the most remarkable in-ease and transformation of the epithelial element, and of the areolar sue lying under the basement membrane. In the skin the thick d hard epithelium is termed *cuticle* or *epidermis*, and the dense and ered areolar tissue constitutes by far the largest proportion of the *tis derma*, or *cutis vera*.

The *external surface* of the skin, formed by the cuticle, (which erywhere adapts itself to the form of the surface on which it rests,)

is marked by furrows of various kinds. Some of these (furrows of motion) occupy the neighbourhood of joints, especially on the side of flexion, and are generally transverse, facilitating the formation and determining the position of the folds that result from the movements of one segment of a limb or another. Others correspond to the insertion of cutaneous muscles; for example, many of those which give force and character to the features; and these are much modified by the quantity of subjacent fat. The elevator muscle of the lower lip thus causes the "double chin." Furrows of another kind are seen in aged and emaciated persons, and after the subsidence of any great distension of the integument, such as that occasioned by anasarca or pregnancy. But, besides these coarser lines, almost every part of the skin is grooved by numberless very minute furrows, which, in the more highly developed regions, run in nearly parallel curved lines, and elsewhere assume a stellated arrangement, or from a close interlacement of no regular figure. Those lines are important, as they depend upon peculiarities in the texture of the skin, having particular relation to the sense of touch: they may be best studied on the palmar aspect of the hand and fingers, and on the sole of the foot. The outer surface of the skin likewise presents innumerable pores, the orifices of the sebaceous follicles and sudoriferous ducts; and the various modifications of the epidermis, termed "appendages of the skin," as hairs, nails, &c., all project on the same aspect.

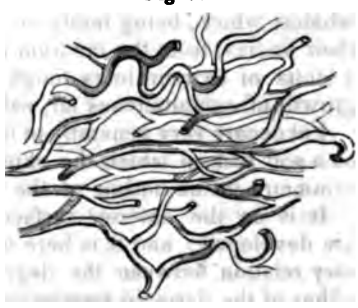
The *deep surface* of the skin is formed by the cutis, or cutis vera, and is attached to the parts which it invests by an extension of the areolar tissue, of which it is itself principally composed, as well as by vessels, nerves, and sometimes muscular fibres, passing into its substance from the subjacent region. It is on this surface that the sweat-glands rest; they are imbedded in it more or less deeply, according to their size, and the length of their excreting ducts; and together with the fatty pellets, so abundant in most parts of the subcutaneous fascia, occasion that areolar or cribriform appearance which is seen on this aspect of a cleanly dissected portion of integument. In preparing such a specimen, it is at once made evident, however great the difference may seem to be between the dense and closely woven texture of the cutis and the lax fascia to which it owes its mobility on subjacent organs, that these tissues blend insensibly together, and are not separated from one another by any abrupt limit. Their ultimate texture is, indeed, essentially the same. Hence the boundary we assign to the skin in this direction is in some measure artificial. Its precise nature will be seen by considering the

Intimate structure of the Cutis.—The white and yellow fibrous elements of the areolar tissue are both much modified, to constitute the framework of this layer; and in different parts of the skin, as might be expected, they exist in different proportions, and in some variety of arrangement. These varieties are not yet made out in all their particulars; but we believe we may state in general, that, where great extensibility, with elasticity, is required, the elastic element predominates (as in the skin of the axilla); and that where, on the contrary, resistance is demanded, the cutis is chiefly composed

ı parallel with the general surface. They are more or less shaped, and vary in size not only with the region of the skin . they are examined, but according to their immediate relation : sudorific ducts, and of other cutaneous appendages which them. This element of the cutis can be easily studied on :ical slices, moistened with acetic acid, which acts on other aving it entire, and, as it were, isolated. (Fig. 77.)

hick and abundant fibres of : *element* twine in great pro- ımong the interstices just d, but what their precise :nts are it is difficult to de- They accompany all the :ssels and nerves, and invest ral small glands with a loose

Fig. 77.



Yellow fibrous element of the cutis of the axilla.—Magnified 320 diameters.

;elatine, which may be ob- ı considerable quantity from , is derived from this latter he cutis, and it is probably ıent also which is principally :d in the changes the skin es during the process of tanning. The varieties in the quali- different skins for this purpose might be explained by a e to those two varying elements of their fibrous framework. ıuseum of King's College is a specimen of excellent leather rom the skin of Bishop, one of the murderers of the Italian o fell a victim to the infamous system of "Burking" many ıce.

anatomists have thought that the contractility of the skin, ed under the influence of cold, and even under certain emo- due to the existence of peculiar fibres; and Gerber has very figured what he considers to be such fibres. He describes

of the meshes, and the absence of fat. It is probable, also, that the phenomenon of "erection" of the nipple is due to the contraction of similar fibres. (*Cyclop. of Anat. and Phys.*, vol. iii. p. 518.)

The thickness and strength of the *cutis*, or *areolar framework of the skin*, differ greatly in different parts according to the amount of resistance required against internal or external pressure. On the hinder surface of the body it is denser than in front, and on the outer than on the inner surfaces of the limbs. It is usually thin over the flexures of the joints. It is particularly delicate on the eyelids, and proportionately so in some other situations, where great mobility is demanded. In regions which are most subject to external pressure, as the soles of the feet, it is firmly united by very dense laminæ, to the subcutaneous fascia; and the intervals between these are provided with pellets of fat, forming a cushion, as an additional means of protection to the delicate organs it encloses and covers.

Among the lower animals we may notice numberless examples of an analogous kind. One of the most striking is that of the great whales, which, being liable to enormous pressure on the surface of their bodies, from the medium in which they live, are provided with a cutis of extraordinary toughness and density, as well as with a growth of subcutaneous fat, called *blubber*, of prodigious thickness.

Fat occurs very generally in the subcutaneous areolar tissue, serving as a soft bed on which the skin may rest, and giving roundness and symmetry to the outline of the body.

It is on the exterior surface of the cutis that the *tactile papillæ* are developed; and it is here to be remarked that there is no necessary relation between the degree of their development, and of that either of the dermoid framework which supports, or the cuticle which covers them. It is true that in the palm and sole all these attain a large size, but, in the back, the tactile organ is well-nigh absent, though the cutis is dense; and in the tongue, on the contrary, this organ is highly developed, while the areolar framework is nothing more than a very thin expansion; and the investment of cuticle is so thin that the papillæ form separate projections from the surface. On the buccal surface of the lips and cheeks, too, the cuticle is comparatively thin.

In all parts of the cutaneous surface, as well as in some portions of the internal mucous tracts, *common sensation* exists, attended with a feeble discriminating power, which must be regarded as the lowest condition of the sense of *touch;* but the organ peculiarly fitted for receiving tactile impressions is concentrated in a very remarkable manner in certain portions of the integument, which in other respects, whether from the precise and varied movements they can perform, or from their peculiar position, are the best adapted to be inlets of this kind of sensation. The palmar surface of the hand and fingers, or the sole of the foot, may be selected for description, as presenting the most highly developed form of the organ of touch.

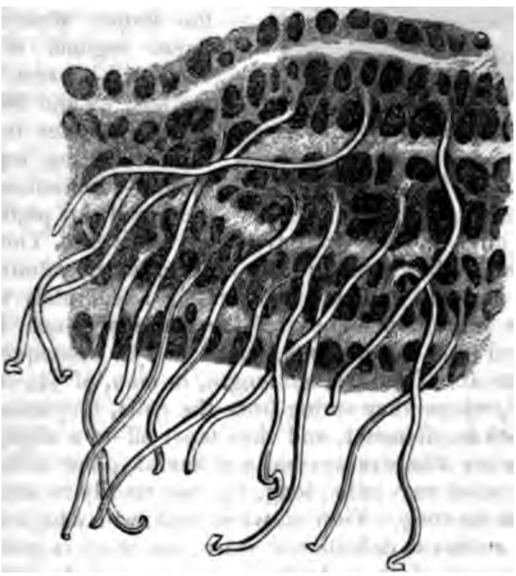
The integument in these regions is finely and regularly furrowed by grooves, separated from one another by corresponding ridges.

rection of these grooves and ridges is various; they run in ıg curves, frequently branch to adapt themselves to the ine- s of the general surface, and differ ıat in width and distinctness. lines indicate the arrangement and ›ment of the tactile organ below. idge is produced by a single or row of elongated conical processes, papillæ, projecting from the sur- the cutis into the epidermis. The ı are occasioned by the epidermis in to occupy the intervals between 's of papillæ. The papillæ in each e usually arranged in pairs, the ls between which are indicated on ›r surface by corresponding minute ry shallow grooves, crossing the the ridges more or less at right Each pair of papillæ thus occu- ittle division of the ridge. In the of each cross line, between the f papillæ, is observed the orifice reat-duct (shortly to be noticed), ›ften is so large as to destroy the haracter of the cross groove. In a square inch of the palm

Fig. 78.

Surface of the skin of the palm, showing the ridges, furrows, cross grooves, and orifices of the sweat-ducts. The scaly texture of the cuticle is indicated by the irregular lines on the surface.—Magnified 20 diam.

Fig. 79.



ırface of the cuticle, detached by maceration from the palm; showing the double rows of s in which the papillæ have been lodged, with the hard epithelium lining the sudoriferous ıeir course through the cutis. Some of these are contorted at the end, where they have ı sweat-gland.—Magnified 30 diameters.

we may generally count rather more than forty rows of papillæ, and in each row rather more than sixty pairs of them.

In the natural state the papillæ are intimately united at all points of their surface to the epidermis which invests them. By a slight maceration this union may be so loosened that the two structures may be readily separated from one another. In gradually tearing off the epidermis, the foregoing account of the arrangement of the papillæ may be fully verified with the aid of a pocket lens. They are seen to form a close pile on the surface of the chorion, each one being lodged in a separate cavity in the deep surface of the cuticle. The papillæ are not equal in size, but frequently a small one is joined with a large one: and the clefts left between them, by the removal of the epidermis, are unequal likewise; those between the rows being deepest, and those between the individuals of a pair being commonly shallower than those between the pairs. This subordination corresponds (though not accurately in degree) with that of the grooves on the outer surface of the cuticle, where the shallow intervals between the individuals of a pair are not even visible at all, being lost by the thickness of the superimposed substance. Such is the exactness of the impression or mould of the papillary structure which the under surface of the epidermis presents, that it furnishes an excellent test of the amount and complication of the former structure in different regions of the skin. This will be seen by comparing figs. 79 and 80; the latter of which, taken from the cuticle of the leg, represents the shallow depressions into which the few dwarf papillary elevations of the cutis in that part have been received. The gradations of size in the papillary structure can be everywhere admirably traced in this way; and will be found to correspond accurately with the account of the relative acuteness of the sense of touch in different parts, deduced from experiments, which will be subsequently given.

Fig. 80.

Under-surface of the cuticle, from the leg:—a. Small creases or furrows. b. Shallow depressions for the papillary structure. c. Epithelium of sudoriferous ducts, corresponding to those in fig. 79.—Magn. 30 diam.

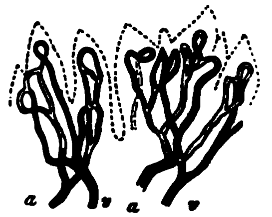
The papillæ are of an average length, in man, of $\frac{1}{100}$ of an inch; at their base, where they spring from the cutis, they measure about $\frac{1}{250}$ of an inch in diameter, and they taper off to a slightly rounded point. They are semi-transparent and flexible; but sufficiently firm in texture to resist maceration long, and not readily to admit of being detached from the cutis. Viewed, when fresh, with a high microscopic power, their outline is definite and sharp, and there is good reason to suppose it formed of an unbroken expansion of the homogeneous basement membrane already spoken of. Within this it is difficult to distinguish any special tissue, except by artificial modes of prepara-

Fig. 81.

Papillæ of the palm, the cuticle being detached.—Magnified 35 diameters.

i. A fibrous structure, however, is ap-
ent, having a more or less vertical ar-
gement: and with the help of solution of
ass, filaments of extreme delicacy, which
m to be of the elastic kind, are generally
overable in it. Injection of the blood-
sels demonstrates the existence of a small
rial twig derived from the arterial plexus
he cutis, entering at the base, advancing
the interior of the papilla, and subdi-
ng into two or more *capillary vessels*, according to the size of the
icular organ. These, after forming small loops, reunite either at
base of the papilla, or in the subjacent texture, into small veins,
ch empty their blood into the venous plexus of the cutis. The
llaries of the smaller papillæ frequently join with those of the fat-
cles that lie beneath. The vascularity of the papillæ is such, that
: presence and relative size may be
rmined simply by the depth of the
ar imparted to a portion of skin by a
l injection of its vessels. The vascu-
y of the integument is therefore, in
ral terms, proportioned to its perfection
n organ of touch.

Fig. 82.



Vessels of papillæ, from the heel: —a. Terminal arterial twig. v. Commencing vein.—Magnified 60 diameters.

nce the discovery of the papillæ as
entient organs, the existence of *nerves*
in them has been usually taken for
ted, or they have been loosely styled
nsions of the nerves; and to the gene-
ruth of such statements we may readily
nt. But we have reason to doubt the
racy of some recent writers, who have professed to give minute
ils of the mode of termination of the nervous tubules in the
llæ. The subject is difficult of investigation. According to
t Burdach (*Beitrag zur Mikroskop. Anat. der Nerven:* Konigsb.
7), and others, the nerves are arranged in a plexiform manner
r the skin of the frog, and loops are formed by the union of
les from neighbouring branches. On examination we find this
ription correct as far as it goes, but that it does not carry us to the
llary structure. The plexus in question is situated underneath
xpansion of fibres crossing each other at right angles, which is
' placed beneath the true skin, and separable from it; and we
observed single tubules from the plexus penetrating this expan-
in their course to the skin. They have then been lost to view.
have hardly been more fortunate in discovering the true termina-
of the nerves in the nictitating membrane of the eye in the same
al, or in the papillary tissue so largely developed on the thumb
certain season.

our attempts to follow the nerves for any distance under the
lary structure in the higher animals, the fibrous tissue (and espe-
r the elastic variety), forming the cutis, has been found so much

to impede the view, that no satisfactory conclusion has been a at. In regard to their presence in the papillæ themselves, w affirm that we have distinctly traced solitary tubules ascending the other tissues of the papillæ about half-way to their summi then becoming lost to sight, either by ending, or else by losing the white sub of Schwann, which alone enables us tinguish them in such situations from textures. Thin vertical sections of p fresh specimens are essential for this i gation, and the observer should tr them the several effects of acetic ac solution of potass. In thus describ nerves of the papillæ from our own o tions, we do not deny the existence loop-like terminations as figured by spectable an authority as Gerber, (*Anatomy, translated by Gulliver,*) b ther do we feel entitled to assent to i have in numerous instances failed to any nerves at all within the papillæ such were plainly visible at their ba when, consequently, the chemical employed could scarcely have de their characteristic structure, had th present. We incline to the belief tubules either entirely or in a great lose the white substance when wit papillæ. We would, however, re reader to what will be found respec nerves of the papillæ of the tongue chapter on taste.

Fig. 83.

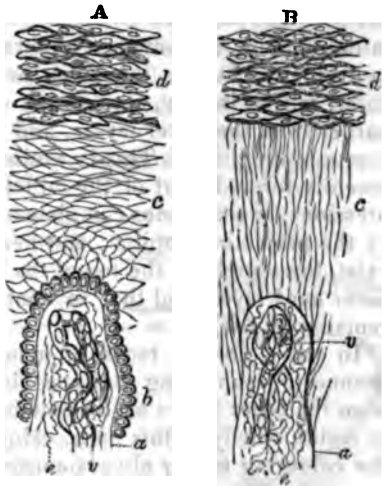
Vertical section of the sole:—*a.* Cuticle; the deep layers (rete mucosum) more coloured than the upper, and their particles rounded; the superficial layers more and more scaly. *b.* Papillary structure. *c.* Cutis. *d.* Sweat-gland, lying in a cavity on the deep surface of the skin, and imbedded in globules of fat. Its duct is seen passing to the surface.—Magnified 40 diameters.

The essential tissue of the papil bably exists even where no projectio enough to be called papillæ are These portions of the skin are more supplied with nerves; and it is from this circumstance, as well as f periments afterwards to be detailed, individual nervous tubules are wid der, and occupy each a more e surface than in parts thickly set pillæ.

The *cuticle*, or *epidermis*, (fig. 83 the cutis, varies greatly in its th As its chief use is that of affording protection, it attains most on parts most exposed to pressure and friction, as the sole feet and the palms of the hands. In the same parts, too, with the amount of pressure to which it is subjected at differe whence the hard hands of the artizan, compared with those o

spent their time in gentler occupations. This increase in probably results from the mechanical stimulus applied to aries of the part. But, in whatever manner it may admit ation, there is scarcely a more striking instance of that inwer which the body possesses of adapting itself to varied ircumstances, than this one presented by the human cuticle. vestment is not permeated by either vessels or nerves, but olely of a congeries of nucleated particles, arranged in superimposed laminæ, and united together by an intervennce in very small quantity. Those particles that lie deepest immediately on the cutis, are little more than small scattered in a homogeneous matrix, which serves to unite ther. Those of the next layers are rounded cells, consistansparent membrane, in which similar granules, but some-r in size, are visible. In the succeeding layers these cells nd more compressed as arer to the surface; and face they are so flatteneir opposite surfaces are t, and adhere, forming s, in which the nucleus The diameter of the les is about $\frac{1}{3000}$ inch, e superficial ones $\frac{1}{600}$

Fig. 84.



A. Section of the skin of the heel, treated with weak solution of potass:—*a*. Basement membrane of papilla. *b*. Layer of nucleated cells resting on the basement membrane. *c*. Several succeeding layers, partially dissolved and their nuclei gone. *d*. Higher layers, not affected by the menstruum. *e*. Elastic fibrous tissue of the papilla. *v*. Its capillary vessel.

B. A similar specimen, treated with strong solution of potass:—*a*, *e*, and *v*, as in A. The layer *b* is wanting, having been displayed. *c*. Converted into a gelatinous mass with striæ. *d*. Unaffected.

The more external layers of the epidermic scales are not represented in these figures.—Magn. 150 diam.

ow that the superficial being continually shed amelliform masses, and ent that their loss is om below; hence new ust be constantly prohe deepest layers, and uninterrupted advance, series of changes, till st off from the surface.* ges are not confined to ; the laminæ they first oist, and comparatively st like a cushion on the itive surface to which lapted, and whose vesthe materials for their nt. The more external ard, horny, and much wann has also pointed out that their chemical properties be-

* le of reptiles and amphibia is periodically cast off in a more or less new one being previously formed beneath it. In amphibia the epiderted; the scales adhering to one another by their edges, and being usually A similar *ecdysis*, or shedding, occurs in the larva state of insects, and idans.

came modified; that at first they are soluble, but afterwards insoluble, in acetic acid; and this circumstance of a chemical change occurring in the stages of their development seems to us so important that we shall illustrate it by two views, fig. 84, A and B. In the former the action of weak solution of potass is shown: the layer of cells immediately resting on the basement membrane, together with the more superficial scales, is but slightly or not at all dissolved; while several intermediate layers are swollen and rendered very transparent, having lost their nuclei. The abruptness of the change is remarkable, and continues after the whole specimen is saturated. In the latter figure a stronger solution has been employed; the deep layer is dissolved, but the superficial scales are still unaffected, while the intermediate part is reduced to a semi-fluid mass, in which scarcely any vestige of structure remains. It is very possible that other agents might disclose further varieties of chemical constitution in smaller subdivisions of the cuticular lamellæ.

These facts will go far to explain why it happens that the union between the particles composing the same layer is in general more intimate than that between different layers, so that it is not difficult to divide the cuticle into two, three, or more laminæ; and, in particular, why it is easy, at a certain stage of maceration, to separate the harder from the softer layers, and thus to isolate the structure termed "rete Malpighii." This is nothing more than the deepest, or most recently formed, part of the cuticle. When isolated, it presents depressions, or sometimes complete apertures, which have been occupied by the projecting papillæ; and hence the term *rete*. When apertures exist, the cuticle on the top of the papillæ has been detached with the outer hard layer, and that in contact with and encircling their bases remains by itself.

In the coloured races of mankind, there is, at first sight, some ground for supposing the rete Malpighii to be a structure distinct from the other layers of the cuticle, the colouring matter being found to reside chiefly in this part. However various in quantity and hue, the colouring matter always consists of oblong or oval grains of extreme minuteness, ($\frac{1}{20000}$ of an inch in their long diameter,) and occupying the interior of some of the epidermic particles. In the negro it is accumulated in enormous quantity, and completely envelops the nuclei immediately resting on the cutis. On examining a vertical section of the whole cuticle, we find the colouring matter gradually diminishing as we approach the surface; and it is most clear that there is no true line of demarkation between the two portions. We may observe the colour of the rete mucosum deeper at points; and a greater proportionate depth of colour is traceable over such points, through all the layers, as far as the surface: we may even discern a sort of stream of coloured grains advancing towards the surface. Hence there can be little doubt that the decrease of colour

Fig. 85.

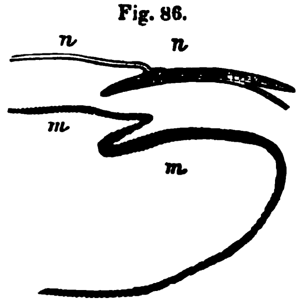
Vertical section of the cuticle, from the scrotum of a negro. *a.* Deep cells, loaded with pigment. *b.* Cells at a higher level, paler and more flattened. *c.* Cells at the surface, scaly and colourless as in the white races.—Magnified 300 diameters.

the superficial laminæ is due to that chemical change which has st been described as gradually taking place in the interior of the pidermic particles. As it is not always easy in this country to obtain ecimens of the negro's skin, the above facts may be verified in the in of coloured domestic animals, or, less satisfactorily, in that of me portions of the skin of the white race, as that of the scrotum, f the nipple during pregnancy; or of accidental moles, or freckles.* he bronzing of parts exposed to the sun is effected by a similar posit of colouring matter in the deeper laminæ of the cuticle.

The subject here referred to has been invested with additional terest by its supposed bearing on the warmly debated question of e specific difference of the negro from the white man. We need t inquire how far the existence of a distinct cuticular lamina might ail the advocates of such a difference, for we may freely state our nviction that no such peculiar layer exists. The sole variety is in e presence of pigment—which may occur, partially, under many rcumstances in the white races, and may be wanting in the true gro. (*See Dr. Prichard, Natural History of Man.*) The reader of e preceding paragraphs will understand how little such processes as aceration, and even the most delicate dissection by the naked eye, d with ordinary instruments, are to be depended on for the deter-ination simply of the anatomical fact.

The *nails* and *hairs* are peculiar modifications of the epidermis, and nsist essentially of nucleated particles.

Fig. 86.



Section of the skin on the end of the finger:—The cuticle and nail *n*, detached from the cutis and matrix, *m*.

The *nails* are flattened, elastic, horny, otective coverings, placed on the dorsal rface of the terminal phalanges of the nds and feet, and projecting beyond the th. Hoofs, claws, &c., are varieties them. The nail has a *root*, or part ncealed within a fold of the cutis; a ly, or exposed part attached to the sur-e of the cutis; and a free or projecting e. The cutis underneath the root and ly is termed the *matrix*, from its being producing organ of the nail. This is ck and highly vascular, and its colour seen through the transparent tissue. ar the root it is white, and occasions the appearance termed *lunula*. e nail has a firm adhesion to the matrix, and is moulded upon it, e the epidermis in other situations. The true epidermis (as dis-guished from the nail), is continuous with the nail at the whole cumference of its body; the root dips into the fold of cutis, within epidermis, and the free edge projects beyond it. In the advanced us we find the edge of the nail to be directly continuous with the dermis of the end of the finger, and only to become free by a ture of this connection after birth. Thus the nail covers that tion of cutis which is without cuticle. It has been frequently cussed whether the cuticle is continued over and under the nail;

* Dr. Simon of Berlin has ably investigated this part of the subject.—Müller's hiv. 1840.

but this is a question of words only, the nail being the same essential structure as the cuticle. The border of the root of the nail is jagged, thin, and soft, and consists of newly formed substances; the deep surface of the body is also soft, and marked by longitudinal grooves, corresponding to the papillary ridges on the surface of the matrix. These soft under-parts consist of nucleated particles, similar to those of the deep layers of the epidermis. The more superficial laminæ of the nail are more and more dense and fibrous; but when treated with acetic acid, some imperfect traces of nuclei may still be detected in them. The nail grows both at the root and on the deep surface of the body; as the substance furnished by the root advances towards the free edge, it receives accessions from the surface of the matrix.

Hairs are found on all parts of the surface, except the palms of the hands and the soles of the feet, and differ much in length, thickness, shape, and colour, according to situation, age, sex, family, or race. We may select one of average size for a description of their structure and mode of growth. The *shaft* of the hair is that part which is fully formed, and which projects beyond the surface. Tracing this into the skin, we find it lodged in a follicular involution of the basement membrane (fig. 87, *a*), which usually passes through the cutis into the subcutaneous areolar tissue. This *hair-follicle* is bulbous at its deepest part, like the hair which it contains. Its sides have a cuticular lining, *b*, continuous with the epidermis, and resembling the cuticle in the rounded form of its deep cells, and the scaly character of the more superficial ones, which are here in contact with the outside of the hair, *c*. The hair grows from the bottom of the follicle, and the cells of the deepest stratum there resting on the basement membrane are very similar to those which in other parts are transformed into scales of cuticle. A gradual enlargement occurs in these cells as they mount in the soft bulb of the hair, which, indeed, owes its size to this circumstance. If the hair is to be coloured, the pigment grains are also here developed—for the most part in scattered cells, which may send out radiating processes—at other times, in a diffused manner around the nuclei of the cells generally. It frequently happens that the cells in the axis of the bulk become loaded with pigment at one period, and not at another; so that, as they pass upwards in the shaft, a dark central tract is produced of greater or

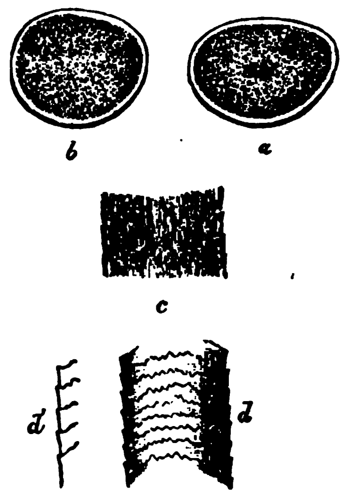
Fig. 87.

Bulb of a small black hair, from the scrotum, seen in section. *a.* Basement membrane of the follicle. *b.* Layer of epidermic cells resting upon it, and becoming more scaly as they approach *c*, a layer of imbricated cells, forming the outer lamina, or *cortex*, of the hair. These imbricated cells are seen more flattened and compressed, the higher they are traced on the bulb. Within the cortex is the proper substance of the hair, consisting at the base, where it rests on the basement membrane, of small angular cells scarcely larger than their nuclei. At *d*, these cells are more bulky, and the bulb consequently thicker; there is also pigment developed in many of them more or less abundantly. Above *d*, they assume a decidedly fibrous character, and become condensed. *e.* A mass of cells in the axis of the hair, much loaded with pigment.

th, often only in irregular patches, and the hair appears here
: to be tubular, *e*. The shaft is much narrower than the bulb,
oduced by the rather abrupt condensation and elongation into
es of the cells, both of those which contain pigment and
ich do not. These fibres may be demonstrated by simply
small fragments of hair, but they become more conspicuous
tissue is softened by a strong acid. The granules of pigment
a linear arrangement between the fibres, which are firmly
to a solid rod by a material similar, it may be supposed, to
:h cements the scales of the cuticle.

ntral series of cells just mentioned, when filled with pigment,
s disposed to become fibrous than those around; and some
ave described it as a *medulla*,
tion from the fibrous part of
, which they then term *cortex*.
tubular character, however
in the hair of many animals,
riable in human hair, both in
situations, and in the same
lifferent points of its length,
e seen very well by means of
e sections (fig. 88, *a*, *b*).*
iman hair has a proper bark,
formed in the following way.
layer of the cells immediately
ng those about to form the
sue of the shaft are seen near
n of the follicle to assume an
d arrangement (fig. 87. *c*),
ally to mount on the hair,
; more compressed against it
ascent, until they form upon
e a thin transparent colour-
in which the overlapping of
ite cells is still exhibited by
nd exceedingly fine sinuous
s (fig. 88, *d*, *d'*). The fibrous
ind this peculiar cortex to-
mpose the shaft of the hair.
ontinual emergence of fresh
of the shaft from the follicle,
of the cuticular lining of the latter are apt to be drawn up

Fig. 88.



a. Transverse section of a hair of the head, showing the exterior cortex, the fibrous tissue with its scattered pigment, and a central space filled with pigment. *b*. A similar section of a hair, at a point where no aggregation of pigment in the axis exists. *c*. Longitudinal section, without a central cavity, showing the imbrication of the cortex, and the arrangement of the pigment in the fibrous part. *d*. Surface, showing the sinuous transverse lines formed by the edges of the cortical scales. *d'*. A portion of the margin, showing their imbrication. Magn. 150 diam.

erse sections of extreme thinness may be made by fixing a lock of hair
o pieces of card or wood in a vice, and then shaving it with a razor. In
als, as the horse and dog, the hairs are tubular. In others they present a
es of cells, round or compressed, with or without pigment, as in the cat
In others, again, their external surface is regularly marked by annular,
nes toothed projections, as in the Indian bat: and numerous other varieties
umerated. The quills of the porcupine, and the feathers of birds, are
s of the epidermic tissue, and, in their essential characters, are closely
irs. See Busk, in Microsc. Journal.

upon the hair, aided, probably, in this, by the imbrication of its surface, and are often found clinging around it for some way; but they are not to be regarded as any part of the hair itself.

In the larger hairs there is usually a double series of these imbricated cortical scales; the outer having its teeth interlocked with those of the inner, but apparently but loosely adherent to them. This outer series seems to be intermediate between the true cortex and the cuticle of the follicle, and to belong rather to the latter, since it does not appear upon the extended portion of the hair. The cortex is much denser than even the fibrous part of the hair, and is less acted upon by strong solution of potass.

From the preceding description it will be evident that the fibrous part of the hair is a peculiar development of the cuticular cells resting on the bottom of the follicle, that the imbricated cortex is formed by a single series differently developed at the circumference of these, and that beyond this series comes the cuticular lining of the follicle; so that the hair is neither covered nor underlaid by cuticle, but it is in fact the modified cuticle of the bottom of the follicle. A thin layer of papillary tissue probably coats the bottom of the follicle in most cases; and where the hairs are large, and especially where they serve principally as tactile organs, there may be a projection of a true papilla, furnished with nerves and capillaries, into the bulb of the hair, as is very conspicuous in the whiskers of some animals and in the quills of the porcupine An approach to this papillary projection may be frequently seen in the hairs of man; but its real size appears to have been much overrated, from the basement membrane having been overlooked. Where a papilla exists, the basement membrane is of course continued over it, and separates it from the true hair, which is never penetrated by either vessels or nerves.

The sebaceous glands of the skin very generally open into the hair follicles at a short distance from the surface.

The hair follicle is fixed more or less firmly in its place, according to the size and stiffness of the hair, by the dermoid and subdermoid tissues uniting intimately with it on its deep or convex surface, where also are spread out the capillary vessels which furnish the materials of growth. These latter are adapted in number to the dimensions of the follicle.

Thus the hairs, like the cuticle, are beautifully organized, and maintain a vital, though not a vascular, connection with the body. Some evidence of their retaining a degree of vitality is found in the fact, first pointed out by Mandl, and verified in some instances by ourselves, that hairs have a tendency to become pointed after having been cut short off. The process is very slow, and seems to consist in a further condensation and elongation of the elementary cells at the new extremity.

Well-authenticated instances have occurred, in which the hair has grown white in a single night, from the sudden influence of some depressing passion; and some have held this circumstance a proof that fluids circulate through them. It seems most probable that this phenomenon results from the secretion, at the bulb, of some fluid—

erhaps an acid, as Vauquelin supposes—which percolates the tissue f the hair, and chemically destroys the colouring matter. The rdinary gray hairs of age resemble other hairs in every respect but olour, and the process of change from dark to gray seems to take lace rapidly in each individual hair.

According to Vauquelin, the colour of hair depends on the presence of a peculiar oil, which is of a sepia tint in dark hair, bloodred in red hair, and yellowish in fair hair. When extracted, as it may be by alcohol or æther, the hair is left of a grayish yellow. The colour is destroyed by chlorine, and probably otherwise resembles closely that of the cuticle in the dark races. The substance of hairs is similar in chemical composition to that of horn. After being softened by maceration in cold nitric acid, it is soluble in boiling water, and the solution after evaporation becomes a gelatinous mass on cooling. The horny matter is said to be distinguishable from coagulated albumen or fibrine by its being readily soluble in caustic fixed alkalies, but not in caustic ammonia. The ashes of hair amount, according to Vauquelin, to one and a half per cent. of its weight; and contain oxide of iron, a trace of oxide of manganese, of sulphate, phosphate, and carbonate of lime, and of silica. Black hair contains most iron, and light hair least. (*Baly's Müller*, p. 424-5, quoted from Berzelius.)

Hairs, when dry and warm, are easily rendered electrical. They readily attract moisture from the atmosphere, and no doubt from the body also, yielding it again by evaporation, if the air be dry. When moist, they elongate considerably; a property which Saussure took advantage of in the construction of his hygrometer, in which a human hair, by its elongation and shortening in moisture and dryness, is made o turn a delicate index.

The shape of the hairs in different situations offers some variety. n general they taper towards their free end. Those of the head are ften not cylindrical, but compressed on one or both sides, so that heir transverse section is reniform or oval. The eyebrows and eyelashes taper towards both extremities. Hairs also vary in being lank r woolly, permanent or deciduous. The frizzled hair of the negro s one of his most remarkable characteristics, but has all the essential tructural characters of the hairs of the other races.

The diseased condition called *plica Polonica* is a matting together f the hairs from the effusion of a glutinous matter probably from the utaneous glands. It is said that hairs so affected bleed, if cut close to he skin. This, if true, may result from a morbid elongation of the ascular papillæ at their roots. In the whiskers of large animals hese papillæ are so long that they are cut and bleed if the whiskers re shaved off.

In some regions of the skin it appears certain that a *lymphatic network* exists immediately under the surface of the cutis, probably nder its basement membrane. Mercury injected into this network hrough a puncture in the cuticle passes readily into the neigbouring lymphatic trunks, and removal of the cuticle does not injure its meshes. These circumstances may be observed in the penis, scro-

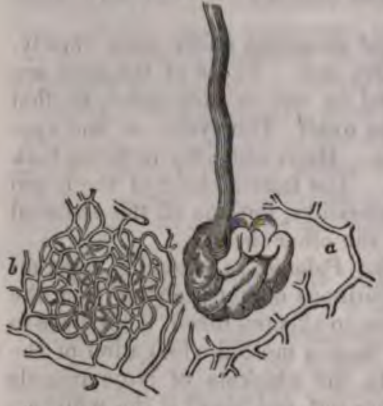
tum, and nipple; but it is probable that the network sometimes exhibited by his procedure in other parts of the skin, is a fallacious appearance due to the mercury having insinuated itself between the cutis and cuticle, in the furrows at the base of the papillary structure; for it does not find its way into the lymphatic trunks, and is deranged by a complete separation of the cuticle. (*Cycl. of Anat. and Phys.*; art. *Lacteal and Lymphatic System:* by Mr. Lane.)

The *sweat-glands* exist under almost every part of the cutaneous surface. They lie in small pits (fig. 83, *d*) on the deep aspect of the cutis; or, if large, entirely in the subcutaneous fascia. As before mentioned, their orifices are discernible in the middle of the cross grooves that intersect the ridges of papillæ on the hands and feet. Here their arrangement is necessarily regular, and their size is about that of a pin's head. But in other parts they are irregularly scattered, though in general in pretty equal numbers over areas of the same dimensions. In certain situations, however, they are very large; and, as might be expected, we find their size and number in different districts of the skin to correspond with the amount of perspiration afforded by each. Thus, they are nowhere so remarkable, or so easily examined, as in the axilla, over a space precisely defined by the growth of the hair in the adult. They here form a layer, which towards the middle, is often an eighth of an inch thick, but thinner towards the edge. It is of a reddish colour, and mammillated by the individual glands which compose it. Some of these are as large as the labial glands, but most of them are somewhat smaller. They are soft, and more or less flattened by lateral apposition with one another. They lie in an atmosphere of delicate areolar tissue, and are covered and permeated with a network of capillary blood-vessels.

Fig. 89.

Vertical section of the skin and sweat-glands of the axilla;—*a*. Layer of glands with their ducts traversing *b*. the cutis and cuticle. *c*. Small hair. *d*, *d*. Portions of larger hairs.—Magn. one and a half diam.

Fig. 90.



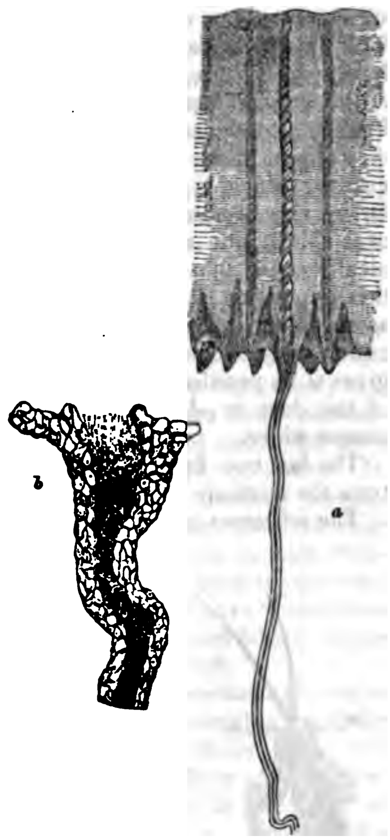
Sweat-gland and the commencement of its duct:—*a*. Venous radicles on the wall of the cell in which the gland rests. This vein anastomoses with others in the vicinity. *b*. Capillaries of the gland separately represented, arising from their arteries, which also anastomose. The blood-vessels are all situated on the outside or deep surface of the tube, in contact with the basement membrane.—Magn. 35 diam.

The sweat-glands can be shown, wherever they exist, by dissecting a piece of fresh integument on its deep surface. They are distinguishable from the pellets of fat, with which they have doubtless been repeatedly confounded, by their pink colour semi-transparent texture. Where the areolar framework of the cutis is densely interwoven, they are less readily discerned, but injection of the blood-

sels makes their detection easy. On detaching one of these glands, highly magnifying it, it is seen to consist of a solitary tube intri-ly ravelled, one end of which is closed, and usually buried within gland; the other emerges n the gland, and opens on the ı. Sometimes this tube is nched, but its diameter is ally very uniform from end end. When very long, the n end forming the duct is a e wider than the rest. The ll is comparatively thick, so t the calibre is not more than hird of the whole diameter. onsists, like the correspond- part of most other glands, of layers: an outer or *basement nbrane*, with which the ves- s are in contact; and an *epi-lium*, lining the interior. The ement membrane is extremely ı, and is continuous with the er surface of the papillæ. The thelium is much thicker, and n involution of the epidermis t rests on the papillæ and s in between them. Hence tube, traced outwards from gland, loses the basement nbrane at the surface of the illæ; and the remainder of course is pursued upwards ugh the successive laminæ uticular scales.

he preparation exhibited in 91 shows the continuity of epithelium lining the ex- ing part of the duct with the cle, and also discloses its lness and cuticular character, e different from that of the eting epithelium within the id, which is soft and easily omposed. We have remarked the duct, in traversing the layers of the cuticle, is lined by epi- nic particles having a different arrangement from those of the cle itself; being flattened in the vertical instead of the horizontal ction, and especially distinct in the deeper and softer stratum of cuticle. This special cuticular tunic of the duct is best exhibited reatment of recent specimens with solution of potass.

Fig. 91.



a Vertical section of the cuticle from the heel, detached by maceration as in fig 79. The epithelium of the sweat-duct, continuous with the cuticle, has been drawn out of the tube of basement membrane, as far as the gland, where it begins to be contorted. The cavity of the duct is seen dilating as it enters the cuticle, and then stretching up to the surface through the epidermic laminæ. The deep surface of the duct is continuous with the surface of the cavities in which the papillæ are lodged.—Magn. 35 diam.

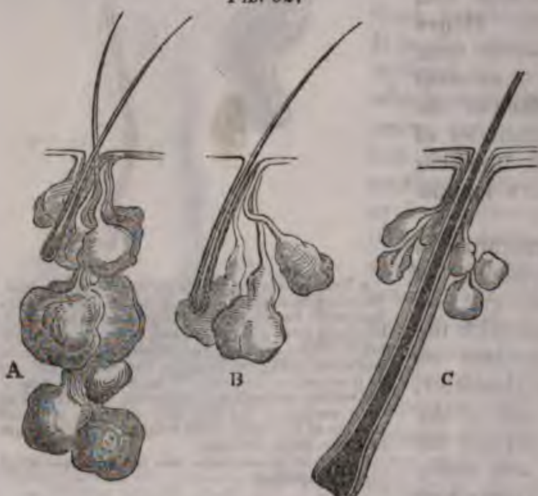
b Duct at its entrance into the cuticle.—More highly magnified.

The duct, on leaving the gland, follows a meandering, and often rather spiral direction, through the areolæ of the cutis, to the interval between the papillæ, where it becomes straight; and it again assumes a spiral course in perforating the cuticle (fig. 83). In the cutis its curves are unequal, elongated, and wide; but, in the cuticle, they are commonly as close and regular as those of a common screw, the form of which may be taken as a fair model of the duct in this part. It is not easy to explain the mode in which the spiral form is given to the cuticular part of the duct. It has been imagined to result from the condensation and flattening of the laminæ of epidermis as they approach the surface; but the fact, that the spirals are not closer near the orifice, is opposed to this notion. Their use, also, is obscure; for we cannot admit the validity of the ingenious idea that the orifice of a spiral tube must be valvular, and, therefore, that they mechanically resist the entrance of foreign substances. If they do offer this opposition, it is only by the tortuosity resulting from the spiral arrangement. The proper tunic of the duct in the substance of the cuticle seems designed to keep it pervious, and may be that which gives it its peculiar spiral form. The average diameter of the cavity of the duct is $\frac{1}{1700}$ inch; but, as it enters the cuticle, it usually becomes wider.

The last two figures, as well as some of the preceding ones, illustrate the anatomy of the sweat-glands.

The *sebaceous glands* are found in most parts of the skin, but are absent from the palms and soles. They are most abundant on the scalp and face (especially about the nose), and about the anus and scrotum. The *glandulæ odoriferæ* of the genital organs are a variety of them, only remarkable by their secretion. The orifices open either on the general surface, or into the hair-follicles, and they lie either in the cutis or subdermoid tissue, according to their size. They are usually associated with the hairs, in the manner represented in fig. 92. They consist of a more or less capacious duct, generally branched, and terminating in blind, pouch-like extremities. The basement membrane of these glands is thicker than that of the

Fig. 92.

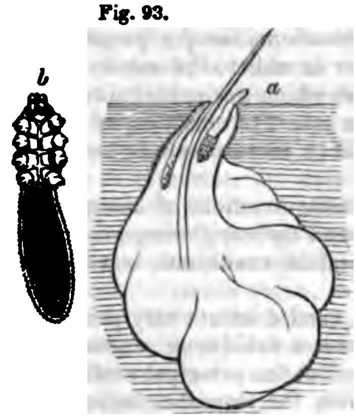


Sebaceous glands, showing their size and relation to the hair-follicles:—A and B from the nose: C from the beard. In the latter the cutis sends down an investment of the hair-follicle.—Magn. 18 diam.

glands, and is lined by an epithelium, in the particles of which :luded granules of sebaceous matter. The terminal vesicles and icts are filled with an accumulation of this epithelium, which, g been detached from the walls, constitutes the secretion. On ep or parenchymal surface of the basement membrane a web of ry vessels is spread out.

iile speaking of the sebaceous glands, we must say a few words arasite so generally found in their ducts in many parts of the that it may almost be regarded as a denizen. This was recently ered by Dr. Simon, of Berlin, (*Müller's Archiv.*, June, 1842,) ias been further described by Mr. Wilson, (*Phil. Transact.*,) who speaks of two principal varieties of the adult animal, distinguished by their length; the one measuring from $\frac{1}{135}$ to e other from $\frac{1}{155}$ to $\frac{1}{165}$ of an inch. He details several interest- rticulars concerning their structure and development, for which we must refer to the original memoir. These singular animals "are found in almost every individual, and especially in those possessing a torpid skin, and they multiply in sickness. In living and healthy persons from one to three or four may be found in each follicle." We have represented them as we have found them in a sebaceous follicle of the scalp (fig. 93).

Fig. 93.



a from the sebaceous follicles:—*a*. Two seen in nary position in the orifice of one of the sebaicles of the scalp. *b*. Short variety. *c*. Long

The *ceruminous glands* of the ear resemble in their structure those just described. They exist in great abundance in the skin of the cartilaginous part of the al meatus, and provide an adhesive secretion calculated to gle particles of dust and small insects, and to prevent their access delicate membrane of the tympanum.*

the functions of the Skin.—Having now considered the several tuents of that very complicated organ, the skin, it remains for take a brief general view of its functions before proceeding to icular account of that one which brought us to this structure, he sense of touch. All these functions have reference to its al anatomical position with respect to the other structures of dy. Regarded as a protective covering, the skin possesses the advantages of toughness, resistance, flexibility, and elasticity. reolar framework of the cutis is the part chiefly conferring these

the sharks and rays there is a remarkable system of mucous tubes opening skin. These tubes are nearly as large as crow-quills, and of great length. ed by a blind extremity, to which a small nerve of the fifth pair is attached.

properties, which are due also in some measure to the epidermis. Both these structures are developed in a degree proportioned to the force and frequency of external contact to which different regions of the body are liable. They are thickest on the palms and soles, on the back of the trunk, and the outer surface of the limbs: thinner on the front of the body, and on the inside of the limbs.

These two elements also afford protection and support to the other more delicate ones with which they are associated. The areolæ of the cutis sustain the intricate networks of blood-vessels, lymphatics, and nerves, which traverse it. The sweat-glands are imbedded in cavities accurately fitted to receive them; and their ducts, with the sebaceous follicles, and hairs, are all lodged in channels or spaces adapted to their respective sizes. The epidermis is a defensive investment to the tactile organ, and, while it shields it from the injurious effects of pressure, is the medium through which impressions of contact are conveyed to it with admirable nicety and truth. The epidermis furnishes also special organs, such as nails and hairs; which are developed in particular situations, for the purposes of defence, the preservation of warmth, or as aids to the sense of touch. The infinite variety of modifications which the epidermis presents among the lower animals, joined with others of nearly equal diversity in the neighbouring textures, adapt it to very numerous and even opposite uses in the animal kingdom.

The skin combines the opposite functions of *absorption* and *secretion*. Its lymphatic network, and the capillaries, are both concerned in the former, which, under certain conditions, is very actively performed.

Secretion may be said to be carried on at every point of the surface of the cutis, since the cuticle is a deciduous product, constantly in course of separation from it. But the principal seat of this function are those glandular offsets from the skin that lie scattered in numberless multitudes beneath it. It may be safely said, that the secreting membrane they comprise far exceeds, in extent, the surface of the whole body. By the involutions of the sweat-glands, the surface is multiplied, for the sole purpose of secretion, and the quantity of material capable of being thus eliminated is enormous. There is one peculiarity connected with this great glandular surface, which results from its not being made up into a solid organ, but disseminated in detached points under the integument, viz., that it is more than all others subject to the influence of external temperature, acting upon the cutaneous blood-vessels; but an apparatus for adjusting the irregularities hence resulting is provided in the kidneys, as will be hereafter explained.

The sebaceous glands are another great system, chiefly subservient to the protection and health of the skin itself, but resembling the sweat-glands in their disseminated arrangement. They are extremely numerous, and yield an oily material for the lubrication of the surface of the cuticle. On most parts of the body they are as abundant as the hairs themselves. They are an important accessory organ for the elimination of hydro-carbonous matters from the system. Thus the

ıperficial emunctory of great extent and importance, and
d subsequent consideration in that character.
now consider the function of the skin as the *organ of touch.*
distinguishing characteristics of this sense is its universal
er the exterior of the body, by which its sphere of action
nt of impressions, and as a criterion of locality, is rendered
sive than that of any other. The contact of foreign bodies
d as occurring at the point at which they actually strike the
uch, whether that point be within the sphere of operation
r sense or not. The precision with which this is effected
ery much on the degree of development of the papillary
e several regions of the body.
already seen that the papillæ present great varieties in
arts. These varieties will be found to correspond very
differences in the mobility of such parts. In general,
st acute in regions best suited, by their structure, for easy
fied contact with external substances; for the power of
rmining the position, direction, and amount of pressure
rgan of touch, is essential to the perfection of the sense.
n not only excite and check the contractions of the mus-
able to regulate their force and duration with wonderful
for, by the *muscular sense*, as stated in a previous chapter,
able to appreciate the state of contraction of a muscle by
originating in the nerves supplied to its fibres. This
h of recognizing and governing the muscular movements,
earliest infancy brought into association with the impres-
ed from the tactile organ, and made accessory to its func-
he perfection to which habit, in numerous instances, brings
f touch, is chiefly due to an improved capacity it confers,
ting the impressions made on the organ, in connection with
muscular movement.

, as in man, we may notice the local concentration of the sense in
ience to this relation of mobility. In monkeys the fingers are highly
it, and the papillæ there developed closely resemble those on the human
prehensile tails of certain tribes possess great mobility, can readily be
ound an object, and are largely supplied with nerves and papillæ. In
is, there is an absence of hair from that surface adapted for contact with
me ant-eaters the tail is highly tactile, and likewise in the chameleon.
ne and feline races the sense of touch resides in the paws, which pre-
apillary structure; in the lips, where the whiskers are developed; and
. In ruminants and solipeds it has its special seat in the lips, which are
ovable, and largely supplied with sensitive and motor nerves. The
the rhinoceros is an excellent example of these conditions; and, still
mout of the tapir and the trunk of the elephant, where the integuments
ice of the nostrils are endowed with exquisite powers both of sense and

re, perhaps, is the sense of touch more acute than in the membranous
f the wings of bats, whereby they are enabled to traverse dark and tor-
s, in rapid flight, without injury. Spallanzani blinded them with a view
g whether sight conferred any part of this singular power, but found
lation interfered in no respect with the faculty. They were still able to
ce between suspended threads without touching them. He could not
ssible that so wonderful an endowment could depend on any exaltation
h, and he resorted to the supposition of the existence of a sixth sense,
some unknown mode of action. But Cuvier, with more sagacity, has

referred it to an eminent sensibility of the nerves, which are profusely expanded over the web of the wings. This membrane seems admirably calculated to receive exact impressions from the vibrations of the air, and so to be a means whereby the animal may be informed of the distance and figure of the neighbouring objects, which reflect or otherwise modify the undulations of the surrounding medium. It is very probable that hearing also may be concerned in this power.

In man, as compared with animals, the sense of touch is extensively diffused; but very interesting differences in its intensity are observable in different parts of the surface, which have been especially illustrated by the experiments of Weber.

These consisted in placing the two points of a pair of compasses, blunted with sealing-wax, at different distances asunder, and in various directions, upon different parts of the skin of an individual, who was not permitted to see the bodies in contact with him. It was then found, that the smallest distance at which the contact can be distinguished to be double, varies in different parts between the thirty-sixth of an inch and three inches; and this seems a happy criterion of the acuteness of the sense. We recognize a double impression on very sensible parts of the skin, though the points are very near each other; while, in parts of obtuse sensibility, the impression is of a single point, although they may be, in reality, far asunder.

In many parts we perceive the distance and situation of two points more distinctly when placed transversely than when placed longitudinally, and *vice versâ*. For example, in the middle of the arm or forearm, points are separately felt at a distance of two inches, if placed crosswise; but scarcely so at a distance of three, if directed lengthwise to the limb.

Two points at a fixed distance apart feel as if more widely separated when placed on a very sensitive part, than when touching a surface of blunter sensibility. This may be easily shown by drawing them over regions differently endowed; they will seem to open as they approach parts acutely sensible, and *vice versâ*.

If contact be more forcibly made by one of the points than by the other, the feebler ceases to be distinguished; the stronger impression having a tendency to obscure the weaker, in proportion to its excess of intensity.

Two points at a fixed distance are distinguished more clearly when brought into contact with surfaces varying in structure and use, than when applied to the same surface, as, for example, on the internal and external surface of the lips, or the front and back of the finger.

Of the extremities, the least sensitive parts are the middle regions of the chief segments, the arm, fore-arm, thigh, and leg. The convexities of the joints are more sensible than the concavities.

The hand and foot greatly excel the arm and leg, and the hand the foot. The palms and soles respectively excel the opposite surface, which are even surpassed by the lower parts of the forearm and leg. On the palmar aspect of the hand the acuteness of the sense corresponds very accurately with the development of the rows of papillæ;

ıd where these papillæ are almost wanting, as opposite the flexions the joints, it is feeble.

The scalp has a blunter sensibility than any other part of the head, ıd the neck does not even equal the scalp. The skin of the face more and more sensible as we approach the middle line; and the › of the nose and red part of the lips are acutely so, and only inferior the tip of the tongue. This last, in a space of a few square lines, ıceeds the most sensitive parts of the fingers; and points of contact ith it may be generally perceived distinctly from one another, when ıly one-third of a line intervenes between them. As we recede from ıe tip along the back or sides of the tongue, we find the sense of ıuch much duller.

The sensibility of the surface of the trunk is inferior to that of the ıtremities or head. The flanks and nipples, which are so sensitive › tickling, are comparatively blunt in regard to the appreciation of ıe distance between points of contact. Points placed on opposite des of the middle line, either before or behind, are better distinuished than when both are on the same side.

The above are the results obtained by making the several parts ıere passive and motionless recipients of impressions. They evince ıe precision of the sense in so far only as it depends on the organiation of the tactile surface. The augmented power derived from hange of position of the object with regard to the surface, is well lustrated by keeping the hand passive, while the object is made to ıove rapidly over it. In this case the contact of the two points is eparately perceived, when so close that they would, if stationary, eem as one. If, still further, the fingers be made to freely traverse ıe surface of an object, under the guidance of the mind, the appreiation of contact will be far more exquisite, in proportion to the ariety of the movements, and the attention given to them. We are hen said to *feel*, or to examine by the sense of touch.

How great is the aid thus capable of being afforded, is manifest in ıe following experiment. With shut eyes, and the hand still, let nother apply to the finger various articles, such as books, paper, lass, metals, wood, cork, &c.; they will be very imperfectly disnguished. That our power of varying the force of contact adds ıuch to the delicacy of touch, is evident from this: that a plane surıce may be made to seem concave, by drawing it over the passive p of the finger of a person whose eyes are covered, provided it be ressed at first strongly, then lightly, then strongly again; or it may e made to seem convex by reversing these gradations of pressure. ıut, if the individual himself is the regulator of the pressure, the eception vanishes. We may obtain some knowledge of the irreguırities of surfaces, and the shape of objects, by simply bringing the ıctile organ into contact with them; but much more by moving it ver them with attention. Thus, too, the infinite diversities of texıre may be made distinguishable by the education of tact combined rith that of the muscular sense. It is related of Saunderson, the lind professor of mathematics at Cambridge, that he could distinguish spurious from a genuine medal, when the deception had imposed

upon connoisseurs; and the case of the blind man, referred to by Rudolphi, who was able to distinguish between woollen cloths of different colours, of course by some slight variety in their texture, is rendered credible by many well-attested examples of a parallel kind.

Our power of appreciating the *weight* of bodies, as well as resistances in general, depends on those of estimating, separately and in concert, both pressure on the tactile organ and the amount of contractile energy acting in the muscles. Weber performed experiments to ascertain how far we are capable of judging of weight by the mere sense of contact. He found that when two equal weights, every way similar, are placed on corresponding parts of the skin, we may add to or subtract from one of them a certain quantity without the person being able to appreciate the change; and that when the parts bearing the weights, as the hands, are inactively resting upon a table, a much greater alteration may be made in the relative amount of the weights without his perceiving it, than when the same parts are allowed free motion. For example, 32 ounces may thus be altered by from 8 to 12, when the hand is motionless and supported; but only by from 1½ to 4, when the muscles are in action: and this difference is in spite of the greater surface affected (by the counter pressure against the support) in the former than in the latter case. Weber infers that the measure of weight by the mere touch of the skin is more than doubled by the play of the muscles. We believe this estimate to be rather under than over the mark.

The relative power of different parts to estimate weight corresponds very nearly with their relative capacities of touch. Weber discovered that the lips are better estimators of weight than any other part, as we might have anticipated from their delicate sense of touch and their extreme mobility. The fingers and toes are also very delicate instruments of this description. The palms and soles possess this power in a very considerable degree, especially over the heads of the metacarpal and metatarsal bones; while the back, occiput, thorax, abdomen, shoulders, arms, and legs, have very little capacity of estimating weight.

Heat and *cold* are peculiar sensations excited by alterations of temperature on the surface of the body. They are, beyond all other sensations, of a relative rather than of an absolute kind, and are always most marked in contrast. Thus, in the familiar experiment of dipping one hand into hot, and the other into cold water, and then plunging them both into water of an intermediate temperature, the new medium will seem cold to the former and hot to the latter; and natives of the polar and tropical regions of the globe will respectively complain of the warmth or chilliness of our temperate climate when they visit our shores. But it is observable that the sensations of heat and cold, when exalted in degree, resemble each other very nearly. The susceptibility to both is greatest within moderate limits; and impressions of either, when acute and powerful, amount to pain, and soon cease to be distinguishable from one another.

Temperature appears higher in degree when it is applied to a larger surface: thus, water feels hotter when we put our whole hand into it,

an when we only dip a finger; the extent of the sensation augment-g the intensity with which it is appreciated, perhaps by more forcibly tracting the attention.

Sensations of temperature have been usually, and we believe pro-erly, attributed to the nerves of common sensation. These sensa-ons are certainly quite different from touch, both in their peculiar haracters and in the source of excitement; but no less may be said f various other modifications of common sensation, to which it is npossible to assign nerves of special endowment. The existence of bres fitted to be acted on by heat and cold, but by no other stimulus, ay be fairly doubted so long as they are undistinguishable from those f touch, both at their origin from the nervous centre and in their eripheral distribution. Still, however, it may be noted that in certain tates of paralysis, the sensibility to heat and cold may be destroyed, hile common sensation and touch remain.*

The sensation of tickling, tingling, itching, and many others allied o them, are also referrible to the nerves of touch. Respecting tickling, t has been well observed by Weber, that it is most apt to be excited n parts of feeble tactile power.

Impressions made on the organ of touch, as on the other organs of ense, continue perceptible for a period more or less prolonged after he stimulus has ceased to be applied. The sting of a smart blow loes not soon subside; and even the simple contact of any object, as a ring or an article of clothing, with a part of the skin, if long con-inued enough, leaves, after its removal, an impression of its presence, which is apt to deceive the individual for a considerable time. The nfluence of habit on sensation in general, may be well illustrated in he case of the nerves of common sensation and of touch. Impres-ions sufficiently strong in the first instance to arouse the attention, oon become feeble, and in time wholly disregarded, if continued niformly or frequently repeated; although the mind can still, at any oment, take cognizance of them by a voluntary effort. The sen-ations of heat and cold may, by long habit, in like manner come to e unnoticed, or lightly heeded, within certain bounds. This is a atter of common experience, and may be exemplified in the case of e lower classes of society, among whom the privation of the com-rts of warm clothing and lodging, and the absence of the mistaken uxury of over-heated rooms, are compensated for by the possession f that diminished susceptibility to cold, under slight exposures, hich is so remarkable in those subject, in a moderate degree, to the clemencies of the seasons.

Little needs be said of the subjective sensations pertaining to the erves now under consideration. They are among the best known, nd most familiar in the body. The peculiar tingling of a limb asleep," which commonly depends on pressure on its trunk, may esult from morbid changes in the centre; as may likewise sensations f formication, or the creeping of insects, and those of itching, of heat, f chilliness, &c., and lastly of pain of various kinds.

* See an instructive case by Dr. W. Budd, in the Med. Chir. Trans., vol. xxii.

Besides the references in the foot-notes and the various treatises on Physiology and general Anatomy already cited, we may refer on the subject of the preceding chapter to Rudolphi, Grundriss der Physiologie, band ii.;—Weber, de pulsu, resorptione, auditu, et tactu; Lips., 1834;—Breschet et Roussel de Vauzème, Ann. d. Sciences Nat., 1834, tom. i.;—Schwann, Mikroskop. Untersuchungen;—Eble, die Lehre von den Haaren;—Gurlt, Müller's Archiv., 1836;—Van Laer, de structurâ capillorum humanorum; Traj. ad Rhen., 1841.

CHAPTER XV.

OF TASTE.—OF THE MUCOUS MEMBRANE OF THE TONGUE, AND OF ITS SIMPLE AND COMPOUND PAPILLÆ.—NERVES OF TASTE.—NERVES OF TOUCH IN THE TONGUE.—SEAT AND PHENOMENA OF TASTE.

The sense of taste is subservient to the nutritive function by guiding us in the discrimination of the qualities of our food, and is therefore appropriately situated in the mouth, the antechamber to the digestive canal. The food being delayed more or less in this cavity, is brought, by the movements to which it is exposed, into intimate and varied contact with the surface; and, its properties being ascertained while it is still under voluntary control, we are able to reject it or to propel it onwards, according to the impression produced on the nerves of taste.

The mucous membrane of the tongue, as the principal seat of the sense, will now demand description. The muscular apparatus of this organ, though increasing its powers of taste, relates chiefly to its employment in the processes of mastication and deglutition, and will therefore be considered at a future page.

In the mucous membrane of the tongue we find a *chorion*, a *papillary structure*, and an *epidermis* or *epithelium;* all corresponding, in essential characters, with the same constituents of the skin.

The *chorion*, or *cutis*, is tough, but thinner and less dense than in most parts of the skin: it receives the insertion of all the intrinsic muscles of the tongue, which send up their fibres to it in small separate bundles, so that the surface of the tongue is exceedingly mobile, even in its minute portions, and its powers as an organ of touch are thereby much exalted. The termination of the muscular fibres in the fibrous tissue of the chorion can be well seen in thin vertical sections. The chorion contains the ramifications of the vessels and nerves from which the papillary structure is supplied. Both the arteries and veins form plane plexuses, open on all sides, like those of the skin, and respectively connected with the vessels of the papillæ above them.

The *papillary structure* has, in general, this peculiarity, that it is not concealed under the epithelium, but stands out freely from the surface, like the villi of the intestinal tube, occasioning the familiar

which contains fluid and several small otolithes, which, according to Siebold, exhibit remarkable movements.

In Crustacea, the organ still exists as a simple sac. This, as Dr. Arthur Farre has shown, is situate, in the lobster, in the base or first joint of the lesser antenna. Its place is indicated by a tough membrane which covers an oval aperture in the upper surface of this joint; the membrane being a continuation of the same structure which forms the shell, but in which the earthy matter is wanting. Towards the inner and anterior margin of this membrane, there is a small round aperture, through which a bristle may be passed. "On removing this oval membrane, together with a portion of the surrounding shell, the internal organ is brought into view, completely imbedded in the soft integument and muscular structure of the antenna." It consists of a sac, in shape like an auricle, and of a horny structure, like soft quill, suspended in the centre of the joint, free on all sides, and having only a single attachment near the aperture in the oval membrane already described; it nearly fills the cavity of the joint. The sac contains particles of siliceous sand, which find their way into it through the aperture already described, and probably fulfil the office of the otolithes which exist in other classes of animals. Numerous very remarkable ciliated processes are attached to the lower surface of the vestibular sac: they are arranged in a semicircular line. In the neighbourhood of this line the auditory nerve attaches itself to the sac, and forms a plexus, which covers the whole under surface of the sac, extending also towards its upper surface. The nerve is derived from the lesser and greater antennal nerves.

Dr. A. Farre has shown that the cavity situate at the base of the greater antenna is not, as has been hitherto supposed, suited to act as an organ of hearing. It is a conical papilla, abruptly truncated, and having stretched over it a membrane, which is pierced in its centre by an aperture capable of admitting a small bristle. On making a section of this part, nothing more is seen than a narrow canal in the fleshy substance leading perpendicularly from the external orifices, and terminating abruptly at the depth of two lines. A nerve is sent off to this organ from the supra-œsophageal ganglion. Such an organ is very ill-adapted for hearing. Dr. Farre has ascertained that this is the most sensitive part of the body of the lobster; "since, while the mechanical irritation of any other parts excited only a slight movement in the limbs of the animal, when out of water, and somewhat feeble, the touching of this part was immediately followed by a violent and almost spasmodic flapping of the tail." (*Farre on the Organ of Hearing in Crustacea.* Phil. Tr. for 1843, p. 233.)

In Fishes the organ of hearing acquires a considerable increase in the complexity of its organization. It consists of a vestibular sac, with the accession of, in general, three semicircular canals. In the myxine, however, a fish of very low organization, there is only one of these canals. In the lamprey there are only two. The vestibular sac consists of a large sac (*utriculus* of Breschet), into which the semicircular canals open, and with the walls of which they are continuous, and of a small offset from this larger one (the *sacculus* of Breschet). This apparatus is composed of a thin, transparent, elastic membrane. It is filled with fluid, and contains in each sac, either porcelainous bodies (*otolithes*), of beautiful structure and great diversity, as in the osseous fishes, or masses of pulverulent deposit, like powdered chalk (*otokonia*), as in the cartilaginous fishes. These, whether hard or soft, consist of carbonate of lime, and therefore may be quickly decomposed by a mineral acid. The whole of this auditory apparatus is deposited in an excavation of the cranial wall, which communicates with the cavity of the cranium itself, excepting in the rays and sharks, in which it is enclosed by the cranial cartilages. It is suspended in fluid (part, probably, of the cerebro-spinal fluid), which constitutes the analogue of the perilymph in the higher animals. In some fishes, according to Breschet, an additional offset from the larger sac exists, to which he gives the name *cysticule.* All these parts are analogous to the membranous labyrinth of the higher animals, there being nothing to represent the tympanum or the cochlea. In many of the osseous fishes the auditory apparatus has no communication whatever with the exterior. In rays and sharks, however, a prolongation of the labyrinth extends through an opening in the occipital portion of the skull to the surface just beneath the skin. In many fishes, according to Weber, there is an intimate connection between the auditory apparatus and the swimming bladder, although their cavities have no communication with each other.

In Amphibia, the auditory apparatus is closed off from the cranial cavity, and is contained in the cranial bones. It consists of a vestibule with three semicircular canals. In some, there is placed external to this labyrinth a tympanic cavity,

closed on the exterior by a membrane, which is intimately united with, or a portion of, the integument, or a thin layer of cartilage. An osseous pillar (the columella), or a chain of two or three ossicles, extends from the wall of the vestibule to this tympanic membrane, analogous to the tympanic bones in the human subject. In the Reptiles, there is a short canal connected with the vestibule, analogous to the cochlea. The existence of this canal establishes that of a second external opening belonging to the labyrinth, or *fenestra cochleæ*, in addition to the *fenestra vestibuli*. Some of the Reptiles, as the serpents, are devoid of a distinct tympanic cavity; but the existence of a columella beneath the skin indicates a rudimentary state of it. In others, as the tortoises, crocodiles, and lizards, such a cavity exists, with its usual canal of communication with the fauces, the Eustachian tube, and with a columella. The fluid of the labyrinth contains crystalline particles in place of otolithes.

In Birds, the organ of hearing has the same parts as in the higher reptiles. Its labyrinth has the cochlea and semicircular canals, and the two fenestræ, and there is a tympanic cavity with a columella. The cochlea is a very slightly bent canal, divided by a membranous septum into two passages, scala vestibuli, and scala tympani.

In Mammalia, the general characters and structure of the organ of hearing closely resemble those of man.

In examining the anatomy of the human ear, we shall first describe the external ear, next, the middle ear, or tympanum, and lastly, the labyrinth.

Fig. 131.

General view of the external, middle, and internal ear, as seen in a prepared section through a. the auditory canal. *b.* The tympanum or middle ear. *c.* Eustachian tube, leading to the pharynx. *d.* Cochlea; and *e.* Semicircular canals and vestibule, seen on their exterior, as brought into view by dissecting away the surrounding petrous bone. The styloid process projects below; and the inner surface of the carotid canal is seen above the Eustachian tube. From Scarpa.

The *External Ear* comprises the free, expanded part, *auricle* or *pinna*, and the *auditory canal* or *external meatus*.

The *auricle* presents an outer surface, which is on the whole concave, and slightly inclined forwards. On this surface are several eminences and depressions, resulting from the folded, or rather crumpled, form of its cartilaginous basis, and which are seen reversed on the free portion of the opposite surface. These are:—a prominent rim or *helix*, and within it another curved prominence, the *anthelix*,

hich bifurcates above, so as to enclose a space, the *scaphoid fossa*, nd describes a circuit round a deep, capacious, central cup, the *ncha*. At the end of the helix, in front of the concha, is a small etached eminence, the *tragus*, so named from its bearing a tuft of air resembling a goat's beard. Opposite this, behind and below e concha, is the *antitragus*. Below is the pendulous *lobe*, comosed of dense areolar and adipose tissues. The *concha* is imperctly divided into an upper and a lower part by the anterior curved xtremity of the helix. The *groove of the helix* is continued into the pper division, and the auditory canal leads from the front and eepest part of the lower division where it is overhung by the tragus nd its protective tuft of hairs. The cartilage of the pinna consists f one principal piece, from which that of the tragus and antitragus s separated by a fissure filled up by fibrous membrane. It is very lexible, and elastic, has a yellowish colour, and belongs to the same ategory as the cartilages of the alæ nasi, &c. Ligamentous fibres ind the concha behind and above, and the tragus in front to the one and fascia in the neighbourhood. A few muscular fibres passing etween different parts of the auricle, serve to impress upon them novements, but so slight as to be hardly worthy of note. These ibres are found externally on the tragus, the antitragus, the upper nd of the helix, and behind on the concha. The whole of the carilaginous part of the ear is rendered movable by three muscles, the *uperior* and *anterior auris*, arising from the epicranial aponeurosis, nd converging to the concha and helix, and the *posterior auris*, assing between the mastoid process and concha.

The *auditory canal* passes from the concha inwards for about an nch, or rather more. It inclines a little forwards, and is slightly bowed, so as to be higher near the middle than at either end. Its width does not equal its height, and it is altogether narrower in the middle. The membrana tympani, which terminates it, is placed obliquely, in consequence of the lower side of the meatus being longer than the upper. The canal consists of two parts, a cartilaginous and fibrous one, and an osseous. To form the first, the cartilage of the concha and tragus is prolonged inwards as far as the auditory process of the temporal bone, and constitutes a tube imperfect at the upper and back part, where its deficiency is supplied by fibrous membrane. This cartilage is rendered still further movable by partial slits in a vertical direction (*incisuræ Santorini*). Muscular fibres are described by some to exist in the meatus, which, according to Haller, become shortened by their contraction. The osseous part of the auditory canal consists in the fœtus of a ring of bone, to which the membrana tympani is attached (*tympanic ring* of the temporal bone). In the adult, it is nearly three-quarters of an inch long, and gives the meatus the form and direction already described.

The skin of the external ear is delicate, and well supplied with vessels and nerves. The orifice of the meatus, besides being concealed behind the tragus, is defended by hairs, and a close arrangement of ceruminous glands, which furnish an abundant secretion, calculated to entangle particles of dust, or small insects, and to pre-

vent their entrance into the organ. These glands are principally seated in the subcutaneous tissue, where the cartilage is deficient, and do not extend into the osseous portion of the canal. The *cerumen* is an oily, very bitter substance, of a yellow colour, and contains, in addition to fat, albumen, and colouring matter, a bitter principle analogous to that of the bile. If not removed from time to time, it is liable to form hard pellets, which either impact the passage, or come into contact with the membrana tympani, and in either case seriously interfere with the transmission of sound to the internal parts. These concretions are partially soluble in ether and turpentine.

The *Middle Ear*, or *tympanic cavity*, is a space filled with air, communicating with the pharynx by the Eustachian tube, and interposed between the external meatus and the labyrinth. It opens behind into the mastoid cells, which are also filled with air, and it is traversed by a chain of moveable bones, connecting the membrana tympani with the vestibule, or common central cavity of the labyrinth. The tympanum is of irregular shape, compressed laterally, and lined by a very delicate ciliated epithelium, prolonged from the pharynx.

The external wall of the tympanum is formed by the *membrana tympani*, and a small extent of the surrounding bone. The membrane is nearly oval, but wider above than below, and as already stated, placed in a slanting direction, so as to form an obtuse angle with the upper wall, and an acute one of about 45° with the floor of the auditory canal. It consists of three laminæ, an external, middle, and internal. The external is derived from the cuticular lining of the canal, and easily detaches itself with that structure after maceration. The middle is strong and fibrous, perhaps analogous to the dermal part of the integument, and attached through the medium of a dense fibrous rim to the bone, which presents a distinct groove for its reception, except above. The handle of the malleus is firmly united to this layer of the membrane, in a vertical direction as far down as the centre, and draws the membrane inwards along that line, so that its outer surface is concave, its inner convex. The abundant small vessels supplying this part run along the handle of the malleus, and thence radiate more or less directly towards the border. The fibrous tissue is in part similarly disposed, and thus seems to have led Sir E. Home to describe a radiating muscle in the membrane, which does not appear to exist. Seen from within, a concentric arrangement of the fibres is more obvious. The inner layer is the ciliated epithelial lining of the cavity, which is easily scraped off for examination in the fresh state (see p. 73).

The *internal wall* of the tympanum (fig. 132) has two orifices of communication with the internal ear; the *fenestra ovalis*, *a*, leading to the vestibule, and the *fenestra rotunda*, *b*, opening into the cochlea. Both these are closed by membrane which prevents the escape of the fluid contained in these inner chambers, and communicates vibrations to it. The fenestra ovalis is likewise occupied by the base of the stapes, one of the chain of ossicles connecting it with the membrana

tympani. Between the fenestræ is the *promontory*, *c*, corresponding to the first turn of the cochlea, and furrowed by two or three canals for the nerves which form the *anastomosis of Jacobson*, *n*. Behind the fenestra ovalis is a conical eminence, the *pyramid*, *d*, hollowed, and presenting a small orifice at its summit, which is on a level with the middle of the vestibular fenestra. The pyramid contains the stapedius muscle, the tendon of which emerges at its summit, and

Fig. 132.

Diagram of the inner wall of the tympanum after maceration, the outer wall and ossicles being removed. *a*. Fenestra ovalis. *b*. Fenestra rotunda. *c*. Promontory. *d*. Pryramid, with the orifice at its apex. *e*. Projection of the aqueductus Fallopii. *f*. Some of the mastoid cells communicating with the tympanum. *g*. Processus cochleariformis, bounding *i*, the canal for the tensor tympani muscle: the anterior pyramid is broken off, if it existed. *h*. Commencement of the Eustachian tube. *j*. Jugular-fossa, immediately below the tympanum. *k*, *k*. Carotid canal, with the artery in outline, to show its course in relation to the tympanum and Eustachian tube. *l*. Portio dura of the seventh pair of nerves, as it would be seen in the terminal part of the aqueduct of Fallopius. *m*. Chorda tympani, leaving the portio dura, and entering a short canal, which opens in the tympanum, at the base of the pyramid. *n*. Grooves for the tympanic plexus.

runs to the neck of the stapes. This muscle is supplied by a twig from the portio dura of the seventh pair. At the base of the pyramid is an aperture through which the chorda tympani, *m*, enters the tympanum. Thence this nerve passes forwards, between the handle of the malleus and the long arm of the incus, and emerges through a canal close to the Glaserian fissure. Above the pyramid an arched prominence, *e*, indicates the course of the aqueductus Fallopii, close to the tympanum; and behind this is the free communication with the mastoid cells, *f*.

The anterior part of the tympanum presents above the canal for the tensor tympani muscle, and below the orifice of the Eustachian tube. The former, *i*, is chiefly formed by a curled plate of bone, the *processus cochleariformis*, *g*, ending in a kind of perforated summit, that some have termed, *anterior pyramid*. This is a little above the fenestra ovalis, and gives passage to the tendon of the tensor tympani, which becomes attached to the short process of the malleus.

The *Eustachian tube*, about one inch and a half in length, leads from the tympanum downwards, forwards, and inwards, to its orifice in the pharynx, which is seen as a slit with an elevated edge close behind the inferior turbinated bone of the nose (see fig. 106, *t*, p. 396). By its straight, but inclined course, the passage of mucus from the tympanum is facilitated. Its upper extremity for more than half an inch is bony, while in the rest of its extent it is cartilaginous. It dilates at each end, especially the lower, where the cartilage is thickened and everted. It forms a passage for the air in and out of the tympanum. It exists in all animals in which a tympanum is found, but in many, the tubes of opposite sides have a common outlet on the pharynx. External to the opening for the Eustachian tube is the opening for the anterior muscle of the malleus (Glaserian fissure) and that for the escape of the chorda tympani.

The *ossicles of the tympanum* are three, the malleus, the incus, and the stapes (fig. 133). The *malleus* (hammer) has a large extremity above, termed the head, *m*, bounded by a constriction or *neck*, from which the *handle* (manubrium), *h*, passes down, imbedded in the membrana tympani, as already described. Its concavity directed outwards explains the similar inequality of that membrane. The *short process* is a slight conical projection from the neck, which receives the insertion of the tensor tympani muscle: the *slender process* (p. gracilis), *g*, also passes from the neck, but forwards and outwards, to enter the Glaserian fissure. On the back of the head and neck an articulation is formed with the incus. The *incus* (anvil), is shaped not unlike a molar tooth. It articulates with the malleus by the anterior surface or summit of its *body*, and has two processes, a *short* and a *long crus:* the former, *sc*, has a backward direction, and projects into the mastoid cells, the latter, *lc*, descends to a level with the fenestra ovalis, bends inwards, and is tipped with a *lenticular process*, to which the head of the stapes is attached, *a*. The *stapes*, or stirrup bone, *s*, is almost sufficiently described by its name. Its construction is truly elegant. It has a *head*, *neck*, *two branches*, and a *base*. The last fits into the fenestra ovalis, to the margin of which it is attached, by membrane, so as to enjoy some freedom of motion. Its neck receives the insertion of the stapedius muscle. The chain of ossicles, now described, stretches across the tympanum by no means in a straight line, and its parts are permitted to enjoy some degree of motion, not merely by the double joint existing between them, but by the mode of their attachment at either end.

Fig. 133.

Ossicles of the left ear articulated, and seen from the outside and below. *m*. Head of the malleus, below which is the constriction, or neck. *g*. Processus gracilis, or long process, at the root of which is the short process. *h*. Manubrium, or handle. *sc*. Short crus; and *lc*, long crus of the incus. The body of this bone is seen articulating with the malleus, and its long crus, through the medium of the orbicular process, here partly concealed, *a*, with the stapes. *s*. Base of the stapes. Magnified three diameters. From Arnold.

These bones are moved by small muscles, two of which are not

uted. These are the *internal muscle of the malleus*, and the *sta-*
us muscle. Each of these muscles consists of striped fibres.

'he *internal muscle of the malleus*, or *tensor tympani*, occupies the al above the osseous portion of the Eustachian tube. It is at-ied in front to the under surface of the petrous bone, and to the tilage of the Eustachian tube; it proceeds backwards, and ends ı tendon which turns abruptly outwards from the osseous canal in ich the muscle is lodged, and is inserted into the short process of malleus. It draws this part inwards, and thus heightens the ten-ı of the membrana tympani. An *anterior muscle of the malleus*, *laxator tympani* muscle, is described by many anatomists as passing n the Glaserian fissure to the processus gracilis. The *stapedius scle* occupies the conical interior of the pyramid; its surface is neurotic, its interior fleshy, and it terminates in a small tendon ich emerges at the apex of the pyramid, and then passes to be erted into the neck of the stapes. In contraction it would fix the pes by pulling its neck backwards. It probably compresses the itents of the vestibule.

Of the Internal Ear, or *Labyrinth*. This is the potential part of organ of hearing, and includes the ultimate distribution of the ve. It consists of three parts, the vestibule, the semicircular als, and the cochlea, all of which, from their delicacy and minute-s of structure, demand careful examination. They are a series of ities hidden in the hardest part of the petrous bone, communicating the outside with the tympanum, by the fenestræ ovalis and rotunda ady described, and on the inside with the internal auditory canal, ich conveys the nerve to them. The very compact bone imme-tely bounding these cavities, considered apart from the less dense e which surrounds it, is termed the *osseous labyrinth*, in distinction a *membranous labyrinth* within.

Of the Osseous Labyrinth.—The singularly complex shape of this t of the organ makes it difficult to describe. 1. The *vestibule*, or mon central cavity, placed immediately to the inner side of the panum, is flattened from side to side, and about a fifth of an inch eight, as well as from before backwards. The semicircular canals n into it by five orifices behind, the cochlea by a single one in nt; on its outer wall is the fenestra ovalis, on its inner several ute holes, including the macula cribrosa for the entrance of a por-ı of the auditory nerve from the internal auditory meatus. At the der part of the inner wall is the orifice of the aqueductus vestibuli, e canal penetrating the vestibule from the posterior surface of the rous bone, and containing, as some describe, a tubular prolongation the lining membrane of the vestibule, ending in a minute pouch ween two layers of the dura mater, within the cranial cavity. schet considers this to be an evidence of a continuity once exist-between the lining membrane of the cranium, and that of the tibule, and it is certain that in most fishes the vestibule is a pro-ı of the cranial cavity, or separated from it only by a membrani-ı septum. Whatever other use the aqueduct of the vestibule may

serve, it seems, certainly, to convey small vessels to the internal ear. The lower part of the inner wall presents a hemispherical depression (*fovea hemispherica*), and immediately above it, and on the upper wall, another, transversely oval and larger (*fovea semi-elliptica*). These are separated by a small *pyramidal eminence.*

Fig. 134.

Osseous labyrinth of the left side. *o.* Fenestra ovalis, leading into the cavity of the vestibule. From this a bristle, †, is passed into *v v*, the vestibular scala of the cochlea, which is laid open in part by the removal of the outer wall. *r.* Fenestra rotunda, seen almost in profile. Through this a bristle, ‡, is passed into the tympanic scala of the cochlea, *t t*, exposed by the removal of part of the membranous portion of the lamina spiralis. The three semicircular canals are seen, with their extremities entering the vestibule, and one end of each dilated into an ampulla. Magnified 3½ diameters. Partly from Sœmmerring.

2. The *semicircular canals* are three in number, all opening at both ends into the vestibule, so that there would be six orifices, were not one of the orifices common to two of the canals. The canals are of unequal length, but all describe more than half a circle, and their cavity is not cylindrical, but slightly compressed on the sides, and about a twentieth of an inch in diameter. Each is dilated at one end into an *ampulla*, of more than twice the diameter of the tube, and at the opposite end it opens out slightly on entering the vestibule. Each canal lies in a different plane, the direction of which being constant, should be carefully noticed in relation to their function. The *superior vertical* canal is also *anterior*, and lies across the petrous bone. It forms about two-thirds of a circle, and its extremities are more divergent than those of the others. In the fœtus the concavity of this canal is free, owing to a deficiency in the substance of the petrous bone, and its arch forms a projection within the cranium, even in the adult. The ampulla is on its outer extremity. The *inferior vertical* canal is also *posterior*, and runs parallel to the posterior surface of the petrous bone, and therefore at right angles to the former. The ampulla is at its lower extremity, and its upper end joins

er end of the former canal, to constitute a common canal an of an inch long, rather wider than those which join to form it, ening behind and below. The *horizontal* canal is also *inferior*, orter than either of the others; its arch is directed outwards ckwards; its ampullar extremity is close to that of the superior l canal.

Fig. 135.

of the osseous labyrinth. V. Vestibule. *a v.* Aqueduct of the vestibule. *o.* Fovea semi- r. Fovea hemispherica. S. Semicircular canals. *s.* Superior. *p.* Posterior. *i.* Inferior. ampullar extremity of each. C. Cochlea. *ac.* Aqueduct of the cochlea. *sv.* Osseous e lamina spiralis, above which is the scala vestibuli, communicating with the vestibule. ympani below the spiral lamina. From Sœmmerring.

'he *cochlea* is, in shape, very like a common snail-shell. It lies horizontally, its apex forwards and outwards, its base marked e bottom of the internal meatus, by a depression exhibiting a rrangement of pores for the reception of the cochlear division auditory nerve. From base to apex extends the irregularly *axis*, *modiolus*, or *columella*, which is perforated by numerous ing channels, ascending from the pores just mentioned, and ting the nervous filaments in regular succession within the ochlear canal which winds around the axis. This *spiral canal* t an inch and a half in length, if measured along its outer nd diminishes gradually in size from the base to the summit ochlea, where it ends in a cul-de-sac. At its commencement out one-tenth of an inch in diameter, but at its termination y half that size. At its base it diverges somewhat from the is, towards the tympanum and vestibule, and presents three gs. Of these, one, free and oval, enters the vestibule; another fenestra rotunda, communicating with the tympanum in the e, but filled up in the recent state by a proper membrane, the *na tympani secundaria;* the third is the minute orifice of the *tus cochleæ*, a funnel-shaped canal leading to the jugular fossa,

and supposed to transmit a small vein. The spiral canal describes about two turns and a half, of which the first, passing round the large base of the modiolus, takes much the widest sweep, so as to encircle most of the second turn. The inner wall of this coiled canal, as has been shown by Ilg, forms the outer wall of the modiolus.

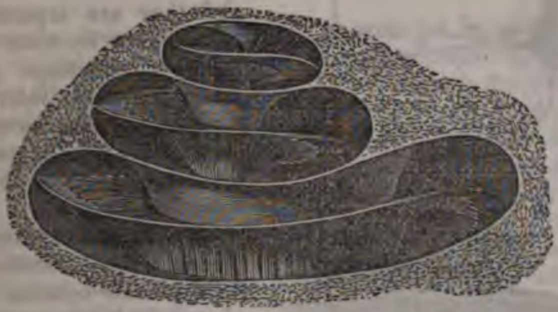
The spiral canal of the cochlea is subdivided into two passages by an osseo-membranous lamina, extended between its modiolar and peripheral wall, and of course taking the same spiral direction as the canal itself. This is the *lamina spiralis*, the fundamental element of the cochlea, on which the nervous tubules are spread out. More than half its breadth on the side of the modiolus is formed by a very brittle osseous process from the modiolus, called the *osseous zone*, enclosing minute channels continuous with those of that part, and transmitting the nerves; its opposite or outer portion is membranous and muscular, and connects the outer thin edge of the osseous zone to the outer wall. The osseous zone commences gradually within the vestibule, and enters the spiral canal between the vestibular and tympanic openings of the cochlea, forming, with the help of the membranous extension, a complete septum between them. The passages, or *scalæ*, into which the spiral lamina divides the canal, correspond, therefore, respectively to those chambers; the upper, towards the apex of the cochlea, *scala vestibuli*, the lower, towards its base, *scala tympani*. These scalæ are, on the whole, pretty equal in size; the vestibular scala is, however, the smaller at the base, the tympanic, near the apex, of the coil; and the latter ceases ere it reaches the summit. At the apex of the cochlea the parts have an arrangement difficult to describe, though easily understood when seen. The axis, no longer hollow, and containing nerves, is reduced to a delicate lamella at about half a turn from the dome-like summit, or *cupola*, formed by the last part of the spiral canal. This lamella, which is the real apex of the modiolus, immediately expands, stretches upwards, and becomes more twisted on itself, so as to include part, or all of the last half turn of the cochlear canal, being termed from its appearance as viewed from below, the *infundibulum*, or funnel. The wide part of this imperfect funnel is directed towards the cupola, with which it blends. It is not open above, but on the side, and it is, in fact, the outside of the last half turn of the canal, projecting into the turn below.

The osseous zone of the spiral lamina ceases with the hollow modiolus at the slender lamella already mentioned, terminating by a small projecting hook (*hamulus*), the concave border of which is free, and directed towards the lamella, so as to leave an opening or deficiency, the *helicotrema* of Breschet, by which the scalæ tympani and vestibuli communicate. The membranous zone connects the convex border of the hook to the outer wall, and is also continued upwards beyond the point of the hook, presenting, however, towards the infundibulum, like the hook itself, a free concave border, contributing to form the orifice of communication.

Such being the form of the osseous labyrinth, we may now proceed to consider the more delicate parts of the organ, and the imme-

te distribution of the auditory nerves. We must premise that the rity of the osseous labyrinth is occupied by a limpid fluid, the *ilymph*, so called by De Blainville, from its surrounding, though the vestibule and semicircular canals only, a hollow membranous paratus, the *membranous labyrinth*, which latter itself contains a nilar fluid, the *endolymph*.

Fig. 136.

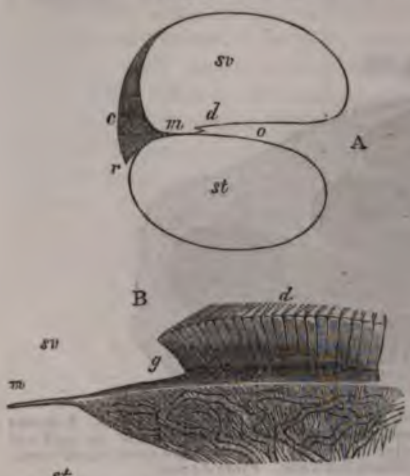


Cochlea of a new-born infant, opened on the side towards the apex of the petrous bone. It shows e general arrangement of the two scalæ, the lamina spiralis, and the distribution of the cochlear rve. At the apex is seen the modiolus expanding into the cupola, where the spiral canal termites in a cul-de-sac. The helicotrema is not visible in this view. From Arnold.

Of the Structure of the Spiral Lamina of the Cochlea.—We shall rm the two surfaces of this lamina tympanic and vestibular, as they gard respectively the tympanic or vestibular scala. The *osseous* ortion of the spiral lamina extends more than half way from the odiolus towards the outer wall, and is perforated, as already deribed, by a series of plexiform canals for the transmission of the ochlear nerves; these canals, taken as a whole, lie close to the wer or tympanic surface, and open at or near the margin of this one. The *vestibular surface* of the osseous zone presents in about e outer fifth of its extent, a remarkable covering, more resembling e texture of cartilage than anything else, but having a peculiar rangement quite unlike any other with which we are acquainted. eing uncertain respecting the office of this structure, we shall term the *denticulate lamina* (figs. 137, and 138), from a beautiful series f teeth, forming its outer margin, which project free into the vesbular scala, and, in the first coil, terminate almost on a level with e margin of the osseous zone, but more within this margin towards e apex of the cochlea. They thus constitute a kind of second argin to the osseous zone, on the vestibular side of the true margin, id having a groove beneath them, which runs along the whole mina spiralis, in the vestibular scala, immediately above the true argin of the osseous zone. The intervals between the teeth are to e seen on their upper surface, on their free edge, and also within is groove, so that the teeth are wedge-shaped, and their upper id under surfaces, traced from the free edge, recede. The free ojecting part, or teeth of the denticulate lamina form less than a urth of its entire breadth, and in the remainder of its extent it ap-

pears to rest on the osseous zone; seen from above, after the osseous zone has been rendered more transparent by weak hydrochloric acid (fig. 138), rows of clear lines may be traced from the teeth at the convex edge, towards the opposite or concave edge of the lamina. These lines appear to be a structure resembling that of the teeth themselves, and they are separated from one another by rows of clear, highly refracting granules, which render the intervals very distinct. These intervals, as seen in the figure, are more or less sinuous and irregularly branched.

Fig. 137.



A. Section of the cochlear canal, where the scalæ are equal. *sv.* Scala vestibuli. *st.* Scala tympani. *o.* Osseous zone of lamina spiralis. *d.* Denticulate lamina. *m.* Membranous zone. *c.* Cochlearis muscle. *r.* Osseous rim of the groove of the cochlearis.

B. Margin of osseous zone, more magnified. *sv.* Scala vestibuli. *st.* Scala tympani. *g.* Groove, between *d*, denticulate lamina, and *m*, membranous zone springing from edge of the osseous zone. *n.* Cochlear nerves and capillaries, distributed on the tympanic surface of the osseous zone.

The denticulate lamina, thus placed on the vestibular surface of the osseous zone, is above, and at some distance from the plexus of the cochlear nerves, which lie near its tympanic surface. The vestibular surface of the osseous zone, including the denticulate lamina, is convex, rising from the free series of teeth towards the modiolus.

In the groove already mentioned there is a series of elongated bodies, not unlike columnar epithelium, in which the nuclei are very faint. These bodies are thick and cubical at one end, and taper much towards the other. They are united in a row; and it is possible they may have some analogy to the club-shaped bodies of Jacob's membrane. We can assign them no use.

Continuous with the thin margin of the osseous zone is the *membranous zone.* This is a transparent glassy lamina, having some resemblance to the elastic laminæ of the cornea, and the capsule of the lens. A narrow belt of it next the osseous zone is smooth, and exhibits no internal structure, while in the rest of its width it is marked by a number of very minute straight lines, radiating outwards from the side of the modiolus. These lines are very delicate at their commencement, become more strongly marked in the middle, and are again fainter ere they cease, which they do at a curved line on the opposite side. Beyond this the membranous zone is again clear, and homogenous, and receives the insertion of the cochlearis muscle. The *inner clear belt* of the membranous zone is little affected by acids. It seems hard and brittle. The middle or *pectinate portion* is more flexible, and tears in the direction of the lines. The *outer clear belt* is swollen, and partially destroyed by the action of acetic acid. Along

CHAPTER XVI.

OF SMELL.—CAVITIES OF THE NOSE.—STRUCTURE OF THE NASAL MUCOUS MEMBRANE.—OLFACTORY REGION.—NERVES OF THE NOSE.—CONDITIONS OF SMELL.

This sense, designed to acquaint us with the odorous qualities of particles suspended or dissolved in the atmosphere, is seated in a portion of the nasal mucous membrane to which the air has access during ordinary breathing, and it may fairly be regarded as appended to the respiratory organ, much as the sense of taste has been seen to pertain to the digestive apparatus. But though it may serve to protect the lungs from the inhalation of deleterious gases, its principal use appears to be that of seconding the impressions of taste in conveying intelligence of the properties of food; for it almost invariably happens, that food possessing a decided flavour has likewise a not less characteristic smell.

Unlike the organs of touch and taste, that in which smell resides has no capacity of movement in relation to its ordinary stimuli; a deficiency quite supplied by the expansion of the chest in breathing, which carries the stream of odorous particles over the sentient surface.

The nose consists, 1, of two chief cavities or *nasal fossæ* separated from one another by a vertical, bony, and cartilaginous septum, and each partially subdivided, by the spongy or turbinated bones, projecting from the outer wall, into three passages or *meatuses:* and, 2, of subordinate chambers, cells, or *sinuses*, of irregular size, hollowed principally in the ethmoid, sphenoid, frontal, and superior maxillary bones, and communicating by narrow apertures with one or other meatus.

The *nasal fossæ* are lofty and of considerable depth, but much narrowed in lateral extent by the projection of the spongy bones towards the septum, which they almost touch. They open in front by the *nostrils*, which, by their horizontal position, direct the air, as it enters, towards the upper region, where the sense of smell is developed; behind, they lead, through a vertical slit on each side, the *posterior nares* or nostrils, into the upper compartment of the pharynx, above the soft palate, into which the food never penetrates, which is strictly a part of the respiratory tract, and which communicates through the Eustachian tubes with the middle ear. The nostrils, as parts of the countenance, and placed as safeguards at the commencement of the air-passages, are more elaborately organized than the posterior nares, which indeed are simple communications, without anything remarkable in their construction, except the shelving of the floor of the nose into the upper surface of the soft palate, favouring the gravitation of mucus from the nose into the pharynx. The nostrils have a cartilaginous framework, which keeps them open, unless forcibly com-

pressed. This framework consists of five principal pieces: one in the middle, the *septal* cartilage, *a*, completing the septum in front; and two on each side, the *lateral* and *alar* cartilages, *b*, *c*, forming respectively the side of the nose below the nasal bones, and the wing of the nose. The former of these is triangular, and rests against the front edge of the septal cartilage; the latter is thinner and more flexible, and curved upon itself to form the dilatable chamber just within the nostril. Several loose nodules or flakes of cartilage frequently exist in connection with the alar cartilages. The nostrils are further supplied with three pairs of muscles; viz., that called by Albinus *compressor naris*, but which is rather a lateral dilator, the *levator* and *depressor alæ nasi*. By these the orifices are dilated when we sniff the air in smelling, as well as under the influence of certain passions. The integuments of the nose are studded with the orifices of sebaceous follicles, which are among the largest in the body, and so numerous as to form a thick continuous layer under the cutis; and immediately within the nostrils is a growth of strong hairs, or *vibrissæ*, designed to obstruct the entrance of injurious substances.

Fig. 102.

Front view of the cartilages of the nose. Above is seen the outline of the nasal bones—*a*. Front edge of the septal cartilage. *b*, *b*. Lateral cartilages. *c*, *c*. Alar cartilages, with their appendages.—After Sœmmerring.

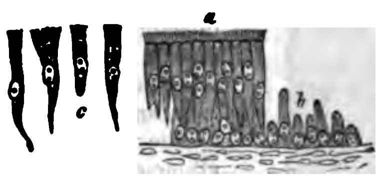
With regard to the interior of the nose, its cavities are formed of bone, generally thin, compact, and laminated, everywhere invested with periosteum. This latter is lined with mucous membrane, the *Schneiderian* or *pituitary membrane*, continuous with the skin of the face at the nostrils, with the mucous covering of the eye through the lachrymal passages, and with that of the pharynx and middle ear through the posterior nares.

The mucous membrane of the nose varies in its structure in different regions. In many situations, especially in the sinuses, it is so intimately connected with the periosteum that that fibrous membrane is in fact a submucous areolar tissue; and the entire lining of the bone has been sometimes called a fibro-mucous membrane, which, as a whole, is delicate in the extreme. On the septum and spongy bones, bounding the direct passage from the nostrils to the throat, the lining membrane is much more thick, partly in consequence of a multitude of glands being disseminated beneath it, and opening upon it, but chiefly perhaps from the presence of ample and capacious submucous plexuses of both arteries and veins, of which the latter are by far the more large and tortuous. These plexuses, lying, as they do, in a region exposed more than any other to external cooling influences, appear to be designed to promote the warmth of the part, and to elevate the temperature of the air on its passage to the lungs. They also serve to explain the tendency to hemorrhage from the nose in cases of general or local plethora.

In the vicinity of the nostrils the mucous membrane exhibits papillæ, and a scaly epithelium, like the corresponding parts of the skin. In the sinuses and in all the lower region of the nose, the epithelium is of extreme delicacy, being of the columnar variety, and clothed with cilia. This being the first occasion on which we have had to speak of this kind of epithelium, we shall briefly describe its structure and mode of growth.

The nucleated particles of which it consists are found in a double series: of which the first, resting on the subjacent basement tissue, is as yet imperfect; and the second, rising to and forming the free external surface of the membrane, is completely developed, and furnished with cilia. The deeper series is the more adherent, and if recent will be found to remain more or less attached, when the superficial and perfect layer has been removed by a gentle stream of water. It will then have the appearance represented at *b*, fig. 103. The nuclei, which are arranged nearly on the same level, are ovoid, and contain usually two nucleoli, even more pellucid than themselves. The surrounding substance is in relatively small quantity, and is seen either as a mere film around the nucleus, or vertically elongated in various degrees. In the superficial series, *a*, the nuclei, though lying on the same general level, are placed some higher and some lower, as if for convenience of package, since the particles bulge where the nuclei are situated. The nuclei are scarcely different in

Fig. 103.



View of the ciliated epithelium of the nose, seen in section:—*a*. Superficial series, clothed with cilia. *b*. Deeper series, becoming elongated vertically. *c*. Various shapes of the perfect ciliated particles.—Magnified 150 diameters.

size or shape from those below. The surrounding granular substance of the particle is, however, much longer than before; below, where it is implanted between the particles of the deep series, it is pointed, though sometimes blunt, and often club-shaped, while the upper end enlarges, and terminates by a flat surface, from which the cilia project, *c*. It must be observed, that the cell-membrane, so apparent in the scaly epithelium heretofore described, is not to be found in this variety. It is either early absorbed, or else so delicate and so united to the contained substance, as not to be distinguishable as a separate object.

It appears clear that this double series of particles constitutes two stages of growth of the same structure. Instances are not wanting of particles intermediate between the two, in which the future surface of the membrane is marked by a horizontal line, above which the granular substance exhibits a vertically fibrous structure, indicative

of the coming cilia. Moreover, we have met with exam which a surface perfectly ciliated was still covered with a l other ciliated particles, that, from their half-dissolved appe had evidently passed their prime, and were in process of This progressive development of the particles as they reced the vascular source of their nutriment, and especially the ev at last of those delicate evidences of life, the ciliary appendag glaring example of the essential independence of the vitality tissues on the blood-vessels, and makes it more easy to conce really subordinate or ministerial office of those channels.

We now come to the proper seat of the sense of smell, paratively limited district of the nasal organ, to which we shal the term *olfactory region*. As this olfactory region has not l been distinguished, nor its character understood, we shall d it somewhat minutely. This, as well as other parts, can l examined in animals, because they can be procured fresh, a state of health. The mucous membrane so soon loses man most interesting features, especially where death has follow chronic disease, that the human subject is not the most fav for the investigation of its physiological anatomy, and can advantageously inspected after the lower animals have fu the general clue. This remark is well illustrated by the instance.

The olfactory region is situated at the top of the nose, imme below the cribriform plate ethmoid bone, through whi olfactory nerves reach the men and it extends about one-th one-fourth, downwards on th tum, and over the superior a of the middle spongy bones ethmoid. Its limits are di marked by a more or less rich brown tint of the epithelium, a remarkable increase in the th of this structure, compared w ciliated region below; so mu that it forms an opaque soft pu the surface of the membran different from the delicate transparent film of the sinus lower spongy bones. The epi indeed here quite alters its ch being no longer ciliated, bu posed of an aggregation of posed nucleated particles, of uniform appearance throughout; except that, in many insta layer of those lying deepest, or almost deepest, is of a darke than the rest, from the brown pigment contained in the ce 104, *b*). These epithelial particles, then, are not ciliated; ar

Fig. 104.

Vertical section of the olfactory region of the nose of the rabbit:—*a*. Surface of the epithelium. *b*. Layer coloured by pigment. *c*. Line of basement membrane. *d*. Nucleated tissue seen below. *e*. Olfactory nervous filament branching.—Magn. 250 diam.

orm a thick, soft, and pulpy stratum, resting on the basement membrane. The deepest layer often adheres after the others are washed away. On looking on the under surface of this epithelium, when it has been detached, we observe projecting tubular fragments, similar to the cuticular lining drawn out of the sweat-ducts of the skin, when the cuticle is removed after maceration (figs. 79 and 80). In fact, glands apparently identical with the sweat-glands exist in this region in great numbers. They dip down in the recesses of the submucous tissue, among the ramifications of the olfactory nerves; and their orifices are very easily seen, after the general brown coat of epithelium has been detached, lying more or less in vertical rows, the arrangement of which is probably determined by the course of those nerves beneath. They become more and more sparing towards the limits of the olfactory region. The epithelium of these glands is milky, and like that of the sweat-glands, contains some pigment. As the duct approaches the epithelium of the general surface, its wall becomes thinner and more transparent; and, in its subsequent course upwards, it is difficult to be traced, for it does not appear to be spiral, or its particles to differ from those which they traverse. We have sometimes seen rods of epithelium, apparently hollow, left projecting from the basement membrane, after the brown epithelium has been washed away; and these are perhaps portions of the excretory ducts of these glands.

A good injection of the nasal organ in the fœtus, both of man and animals, will display a multitude of minute capillary loops upon the surface of the olfactory region, bearing a close resemblance to those of rudimentary papillæ. These loops were first pointed out to us two years ago by Mr. Quekett in the fœtal pig, and also in the human fœtus at its full term; and so clearly did they seem to indicate the presence of true papillæ in this region, that we made repeated and close examinations of the recent organ, in order to expose their structure, supposing them to be concerned in the sense of smell. These researches, pursued on adult specimens, have been hitherto fruitless; at least, we have found no other evidence of papillæ than delicate hollow epithelial processes remaining, after a gentle current of water had washed away the principal portion of the brown epithelial investment—an appearance too ambiguous to be spoken of with confidence. In the human fœtuses we have injected, the loops are such as are represented above (fig. 105). The convexity of the loops presents a decided dilatation, being from $\frac{1}{2000}$ to $\frac{1}{1500}$ of an inch wide, while the diameter of the capillary on either side is only about $\frac{1}{3000}$ inch. We have hitherto failed in seeing any loop-like or projecting capillaries in injections of adult specimens. Care must be taken not to confound these loops in the olfactory region of the fœtus with the loops of the undoubted true papillæ, situated just within the nostrils, and which belong to touch.

Fig. 105.

Dilated loopings of the capillaries of the olfactory region of the Human Fœtus, injected and magnified.

Of the Nerves of the Nose.—These are the first pair, and branches of the fifth pair, besides motor filaments from the facial nerve to the external muscles. The first pair has long been considered as the proper nerve of smell, though not without dispute. That it has been rightly so regarded, however, is evident for many reasons. Its limitation to the upper and middle spongy bones, to the roof of the nasal fossæ, and to the upper half of the septum, where the mucous membrane exhibits peculiar characters, and smell is principally, if not exclusively, exercised; its development in the vertebrate class, proportionate, *cæteris paribus*, to the acuteness of smell, being largest in animals of keenest scent; the loss of smell, without other effect, consequent on its division; together with the perversion or loss of smell found in many authentic cases in connection with disease of these nerves or their associated cerebral region: all these facts point irresistibly to this conclusion.

Of the First Pair.—Under this head are to be described the olfactory process or lobe, and the olfactory filaments distributed to the nose.

The *olfactory process*, or *lobe* (*a*, *b*, fig. 106), is a slender prism

Fig. 106.

Outer wall of the nasal fossa, with the three spongy bones and meatus: the nerves being shown as they would appear through the membrane if it were transparent.—*a*, Olfactory process. *b*, Olfactory bulb (represented rather too short) resting on the cribriform plate. Below is seen the plexiform arrangement of the olfactory filaments on the upper and middle spongy bones. *c*. Fifth nerve within the cranium with its Gasserian ganglion. *d*. Its superior maxillary division, sending branches to Meckel's ganglion, and through that to the three spongy bones, where they anastomose with the olfactory filaments, and with *s*, branches of the nasal division of the ophthalmic nerve. *e*. Posterior palatine twigs from Meckel's ganglion, supplying the soft and hard palate. *t*. Orifice of the Eustachian tube on the side of the pharynx, behind the lower spongy bone.—From Sœmmering, two-thirds diameter.

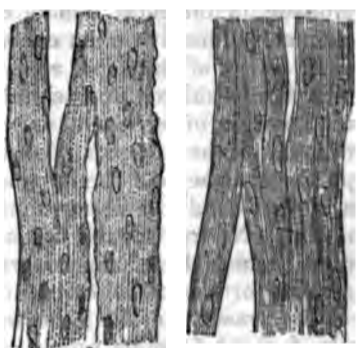
of fibrous and vesicular nervous matter, terminating in front in a bulb; and it is sunk in the fissure which bounds the supra-orbitar convolutions on the under surface of the anterior lobe of the cerebrum (p. 255). It is connected with the inferior surface of the brain by an external and internal root. The former is the longer, and may

the nervous matter forming the floor of the fissure of among the arteries of the locus perforatus, towards the ıter part of the corpus striatum, near the anterior com- ıe cerebrum. In the dog and cat, where this process is the anterior commissure seems to have a more intimate e olfactory processes. In the same animals the white ıe process is continuous also with that of the largely ippocampus major. The internal root winds inwards, the gray matter in front of the optic commissure, near extremity of the corpus callosum. In front of the point ots join, there is a process of gray matter constituting a root, and which is continued forwards as a portion of process, as far as the bulb, where it expands.

ıf the olfactory process (fig. 106, *b*) is an elongated oval 'ous matter, which lies upon the cribriform plate. The ns of the olfactory process terminate in its posterior ex- contains a small ventricle, which, in some of the lower rolonged backwards as for as the cerebral ventricles. e is lined with a delicate white layer, but with this ex- whole olfactory lobe consists of gray matter. In particular bserved, that the under portion, which reposes on the ate, and sends down the olfactory filaments, contains no ı.

ory filaments (figs. 106, 7, 8) are from fifteen to twenty- er, and, passing through the apertures of the cribriform e seen, invested with fibrous sheaths derived from the upon the deep or attached surface of the mucous mem- olfactory region. They here branch, and sparingly re- lexiform manner, as they descend. They form a con- rt of the entire thickness of the membrane, and differ the ordinary cerebral nerves in structure. They contain stance of Schwann, are into elementary fibrillæ, , and finely granular in are invested with a mogeneous membrane, bling the sarcolemma, ctly, that neurilemma ured from the nerves of 64, p. 209. These facts atedly ascertained, and ı be of great importance l question of the func- veral ultimate elements us structure, especially d in connection with said on the anatomy . We are aware that ists deny the existence substance of Schwann as a natural element of the nerve-

Fig. 107.



Olfactory filaments of the Dog:—*a*. In water. *b*. In acetic acid.—Magnified 350 diameters.

fibre in any case, pretending that it is formed by artificial modes of preparation; we hold it to be a true structure; but, however that may be, these nerves never exhibit it, however prepared. They rather correspond with the gelatinous fibres. Now there is no kind of doubt that they are a direct continuation from the vesicular matter of the olfactory bulb. The arrangement of the capillaries in well-injected specimens is a convincing proof of this, as these vessels gradually become elongated on the nerve assuming a fibrous character as it quits the surface of the bulb; and further, no tubular fibres can ever be discovered in the pulp often left upon the orifices of the cribriform plate after detachment of the bulb. It must be remembered, that a few tubular fibres from the nasal nerve of the fifth here and there accompany the true olfactory filaments, but these only serve to make the difference more evident by contrast.

Although these nucleated olfactory filaments lie in great abundance under the mucous membrane of the olfactory region, we have been quite foiled in our attempts to trace their ultimate distribution in the membrane, and the difficulty is attributable to their want of the characteristic white substance. Their elongated nuclei render the larger branches unmistakeable; but if these become resolved at last into fibrous elements, the nuclei cease to be distinct from those of the numerous nucleated tissues which they traverse. In this respect they correspond, in all probability, with the nerves of some of the papillæ of the tongue (see pp. 379–380); and, considering the similarity between the two senses, an argument may be hence deduced for the limitation of the sense of taste to those elementary nerve-fibres going to the tongue which are without the white substance of Schwann. If this be so, the looped tubular fibres are confined to the impressions of touch in that organ.

We are averse from speculating prematurely on the meaning of anatomical facts, but as some hypothesis will intrude itself, we would venture to hint that this amalgamation of the elements of the peripheral part of the olfactory nervous apparatus in the larger branches, and probably in the most remote distribution, as well as the nucleated character indicative of an essential continuity of tissue with the vesicular matter of the lobe, are in accordance with the oneness of the sensation resulting from simultaneous impressions on different parts of this organ of sense, and seem to show that it would be most correct to speak of the first pair of nerves, as a portion of the nervous centre put forward beyond the cranium, in order that it may there receive, as at first hand, the impressions of which the mind is to become cognizant. No true tubular fibres belong to the olfactory nervous apparatus, except those commissural ones passing between the bulb and certain portions of the cerebrum.

The branches of the fifth pair given to the nose (figs. 106 and 108), are derived from its ophthalmic and superior maxillary divisions. The nasal twig of the former, crossing the orbit, passes over the cribriform plate of the ethmoid bone into the nose, in close contact with a portion of the olfactory nerve, and most probably forms some anastomoses with it. Its subsequent course is downwards, subdividing

supply the mucous membrane and skin in the neighbourhood of the terior orifices. The pungent sensation preceding sneezing seems be an affection of this twig, ad the flow of tears that accom- anies that act is accounted for y the common source of this ad of the lachrymal nerve. The asal branches of Meckel's gan- lion enter the nose through the pheno-palatine foramen, or by ores between this and the pos- rior palatine canal, and then pread over the three turbinated ones and the septum nasi, anas- mosing at several points with he olfactory filaments, and with he nasal branch of the ophthal- ic (figs. 106 and 108). When he fifth nerve is diseased, so that nsation is lost generally in the arts supplied by it, a brush may e introduced into the nostril, and ibbed over the surfaces usually o extremely sensitive, without he slightest discomfort to the atient. Similar effects follow division of the nerve. Hence it may e concluded that the fifth gives common sensibility to the nose, in ommon with most of the other parts which it supplies.

Fig. 108.

Nerves of the septum of the Nose:—*a*. Olfactory bulb resting on the cribriform plate, below which its branches may be traced on the septum about half way down. Behind, the naso-palatine nerve from Meckel's ganglion is seen descending to the naso-palatine canal. In front, the nasal twig of the ophthalmic nerve descends towards the tip of the nose, dividing into two principal branches. *p*. Roof of the mouth. *e*. Orifice of the Eustachian tube.—From Arnold, one-half diam.

Conditions of smell.—In addition to the essential conditions of tegrity of the nervous apparatus, and the presence of the requisite timulus, a healthy condition of the epithelial investment of the papillæ eems necessary for perfect smell. If the mucous surface is dry, or f it is in the raw irritable state, attended with watery discharge, duced by cold, smell is impaired or lost. This is explained by nsidering the manner in which the nerves are ordinarily brought nder the influence of the stimulus. As in taste, a solution of the imulus in the surface of the membrane is requisite in order that the dorous substance may actually reach the nerve. Insoluble sub- ances cannot be smelt. Hence, whether the membrane be too dry, r an inordinate excretion of fluid be going on from its surface, the ecessary penetration of the stimulus to the nerves is alike interfered ith. In the latter case, the effect may partly depend also on a ange produced by the inflammatory action, in the excitability of the erves themselves.

Since odorous substances must undergo solution before they can fect the olfactory nerves, why, it may be asked, cannot such sub- ances, if dissolved in water and injected into the nose, be recog- zed by their smell? In answer to this it may be stated, that there no reason to deny the possibility of their being so recognized, as r as the excitability of the nerves is concerned. But the ciliated

epithelium of the nose, and the nerves of common sensation supplying the lining membrane, instantly resent the contact of all other fluids than the film which moistens the surface, and which is naturally furnished by it in due proportion to the exigencies of the part; and when the membrane is thus irritated, and its texture altered by the water, it need not excite surprise that its special sensibility should be altered or disguised. The organ of smell in fishes resembles that of air-breathing animals in every essential point of structure, and differs mainly in the habitual contact of its sentient surface with the surrounding water. It may therefore be concluded, that sensations of smell are excited in it by substances brought to it through the water, corresponding in kind with those brought in the other case through the air, but eventually dissolved in the moisture of the membrane. The nature of the sensation will depend on the special sensibility of the nerve, which in both cases can be excited only by the stimulating substance in solution; and whether air or water brings the stimulus to the surface of the membrane, is made important only by the special adaptation of that surface to the contact of one or the other medium.

We may here notice two important reasons for the situation of the organ of smell, so high up in the nose, in addition to the obvious one of the protection from mechanical injury thus afforded to so delicate a part. These are, that it is thereby screened from the contact of air either too *cold* or too *dry*. The interposition between the outer orifice and the organ of smell of projecting and folded membranes of active secreting powers, and containing large reservoirs of blood (in the plexuses already described), seems designed to answer both these purposes. These parts break the force of the current, warm it, and impart that degree of moisture which is best calculated to aid the solution of the odoriferous particles on the sentient surface to which they are afterwards applied. The remarkable complexity of the lower turbinated bones in animals with acute scent, without any ascertained distribution of the olfactory nerves upon them, has given countenance to the supposition that the fifth nerve may possess some olfactory endowment, and seems not to have been explained by those who rejected that idea. If considered as accessory to the perfection of the sense in the way above alluded to, this striking arrangement will be found consistent with the view which limits the power of smell to the first pair of nerves.

We have already remarked that the exercise of the sense of smell is not attended with more than a general idea of locality. The sensation is even more simple in this respect than that of taste. Unless the experiment be made, we know not that we are constantly exerting the sense on two sides, for the double sensation is perceived as a single one. Our observations on the anatomy of the olfactory nervous apparatus may assist in the explanation of this fact.

The sense of smell may be voluntarily heightened by short and quick inspirations, which drive the air smartly against the upper region of the nose, and thus lead to the more effectual detention of its odoriferous particles by the membrane, while the attention is given to its

nsations. On the other hand, by closing the nostrils, and breathing rough the mouth, all access to the organ of smell is prevented, cept that gradually effected by admixture through the pharynx d posterior nares. It is through this latter channel that the lorous particles of food, rising from the throat to the nose during piration, blend the sensation of smell with that of taste so strongly d habitually, that it becomes difficult to discriminate between em.

Analogy would lead to the belief that the nervous apparatus of nell, if irritated by an internal cause, would be the seat of olfactory nsations. Such *subjective* phenomena have been known to exist certain cases of disease, in which the nerve, or the anterior lobe the brain, has been afterwards found disorganized. Occasionally, o, odours are perceived without the actual presence of the object ually giving rise to them. These also must be regarded as subctive.

The quality of the sense, also, seems to vary not a little in different ersons; some being strongly affected, even to faintness, by a scent hich is almost imperceptible to others. The odours of flowers, for xample, are very variously appreciated, as every one must have more r less observed. There are corresponding idiosyncrasies in the other enses.

On the subjects of this chapter, in addition to the elementary works before quoted, he following may be consulted:—Schneiderius, de osse cribriformi et sensu ac rgano odoratus; Scarpa, de organo olfactus; also, de auditu et olfactu; Sœmmering, ones organi humani olfactus, 1809; H. Cloquet, Osphrésiologie, ou traité des odeurs. Paris, 1821.

CHAPTER XVII.

F VISION.—OF THE ANATOMY OF THE EYEBALL, OPTIC NERVES, AND APPENDAGES.—OF THE PHENOMENA OF VISION.

IT would appear that an animal may be sensible to light without ssessing an organ of vision. Thus, that beautiful little polyp, the *ydra*, shows a decided predilection for the light side of the vessel which it is kept. Most animals, too, require the presence of light r the full performance of their functions; and this is not the case ith animals alone, but with plants likewise: both, in the great marity of instances, pine away in the dark, or fail to arrive at complete evelopment.

But the presence of an *organ of vision* implies something more than e mere power of distinguishing between light and darkness. It ust enable the animal to discern something of the colour, or at least the form, of surrounding objects; and this in a degree proportioned the perfection and complexity of its organization.

The principle on which the organ is constructed seems to be in all cases the same, viz., that of the *camera obscura*—a dark chamber with a small aperture for the admission of light, a quantity of black matter for the absorption of superabundant rays, and a nervous expansion on that wall which receives the rays of light.

Among the lower invertebrata, the eyes, or *ocelli*, consist only of a nervous point, shielded with a minute quantity of colouring matter. The chief additions which increase the complexity of these organs in the higher animals consist of transparent media and lenses for the refraction of the light, and the production of a more precise image; of an apparatus for the regulation of the quantity of light admitted to the retina; and of other appendages for protection and movement.

The position of the human eye at the upper part of the face and directed forwards, while it gives to the countenance its most important element of beauty, adds greatly to the utility of the organ, by increasing the visual range. For protection in this exposed situation, it is sunk deeply in a cushion of fat, within a bony cavity, the *orbit*, the prominent borders of which are well adapted to receive the force of blows directed towards that region. It is furnished with muscles capable of moving it towards any side, and of protruding or sinking it. It is likewise provided with movable lids to guard its exposed surface from mechanical injury, and its nerve from the effects of excessive light; and with a lachrymal apparatus, by which the front of it is continually irrigated with a bland fluid.

In the globe of the eye itself we recognize, as the most essential constituents, the expansion of the optic nerve, called the *retina*; and, in front of this, the *transparent refracting media* which, as a whole, transmit the light so as to bring its rays to a focus upon the nervous sheet. The curved form of the retina, and the rounded figure of the eye thence derived, are perfectly adapted to the curvatures of the refracting media: so that, if the nervous lamina had assumed any other shape, it would have been more or less out of focus, and vision consequently have been indistinct.

To maintain the figure of the retina, and to protect a part of so much delicacy, in which the slightest change of form would be attended with injury to the function, the whole is encased in a dense tunic of great strength, termed the *sclerotica* (σκληρὸς, durus), which is opaque, except in front, where it is modified in structure, becomes perfectly transparent to allow the light to enter, and is known as the *cornea*. Between the sclerotica and the retina is interposed a layer of dark pigment, contained in a delicate membrane termed the *choroid*. In front of the retina are the *transparent media*. One of these (the *vitreous body* or *humor*) is contained immediately within the cup which the retina forms, and appears specially constructed to give it that necessary support inside which the sclerotica furnishes on the outside. The vitreous body occupies four-fifths of the whole globe. Imbedded in its anterior part is a double convex lens (the *crystalline lens* or *body*), which comes nearly up to the cornea; leaving, however, a small cavity containing a watery fluid, the *aqueous humor*, between itself and that transparent part of the external case. Across this

cavity, and dividing it into an *anterior* and *posterior* chamber, hangs a vertical curtain-like process of the choroid, called the *iris*, perforated in the centre by an aperture, *the pupil*, for the admission of light to the interior, and contractile under the influence of light on the retina, in order that it may regulate the amount of light entering the organ. The perfect fluidity of the aqueous humor is a provision to allow of the expansion and contraction of the pupil, and of the movements of the lens itself towards or from the cornea.

The human eye would be nearly globular were it not that the anterior portion, formed by the cornea, is a part of a smaller sphere than the rest, and is therefore slightly protuberant. Hence the antero-posterior axis of the eye is longer than the transverse, in the proportion of twenty to nineteen.

In terrestrial quadrupeds its shape is for the most part nearly similar. In animals that inhabit the water, as Cetacea and fishes, the eye is considerably flattened in front; so that, in some fishes, it is almost a half-sphere. In birds, on the contrary, especially those which fly high, the cornea is very prominent compared with the rest of the eye, which is of a more or less flattened form. These differences have an evident reference to the density or rareness of the medium through which the light passes to the organ.

A more detailed description of the several structures composing the ball of the eye will now be given, in which we shall follow the order most natural to a dissector, viz., that from without, inwards.

The *sclerotic* coat consists of white fibrous tissue, in which, however, the ultimate filaments are more distinct, and less wavy than in ordinary specimens. These form numerous layers, crossing one another chiefly at right angles, and thus constitute a membrane capable of resisting distension, and of retaining its figure under pressure. It has a white glistening aspect, especially in front, where it receives the insertion of the tendons of the four straight muscles, and, being visible, is familiarly known as the "white of the eye." The sclerotic is thickest behind, and becomes gradually thinner in front, till nearly in contact with the cornea, where it increases in strength a little.

In the animal series, the sclerotic becomes of greater relative thickness behind, in proportion to the flattening of the organ in front, and the pressure which it will have to sustain from the surrounding medium. In aquatic mammalia this is effected simply by an accumulation of the fibrous tissue in that situation, as in the whale, where it is often an inch in thickness, a wonderful provision against the enormous pressure to which that animal is exposed at great depths. In reptiles and fishes there is a thick cartilaginous lamina included in the fibrous tissue; and in some this cartilage ossifies, as in the sea-bream, mentioned by Dr. Jacob. In birds, too, where the sclerotica is flattened from before backwards, a thin cartilaginous plate exists in it, which confers a peculiar elasticity and firmness, and is at the same time light and slender. Its anterior part is further fortified by fourteen or fifteen osseous plates, disposed in a regular series round the margin of the cornea. Similar plates occur in various reptiles, and are especially remarkable in those gigantic specimens of this class, the Ichthyosauri and Plesiosauri, which are only known to us by their fossil remains.

The optic nerve comes through the sclerotic behind, at a distance of about its own breadth, or nearly one-eighth of an inch, on the inner side of the axis of the eye, by which is meant the axis of the

dioptric media. This nerve contains a considerable quantity of fibrous tissue separating and supporting its fasciculi, and as it traverses the sclerotic this tissue becomes continuous with the borders of the aperture, so that the aperture itself may be said to be cribriform; the nerve passing through a number of distinct canals of fibrous tissue, before it reaches the inner surface of the sclerotic. It is indifferent whether this cribriform tissue be called neurilemma or sclerotic. One thing, however, may be always observed. The nerve, as it pierces the sclerotic, contracts, and lies in a smaller compass, so that the entire aperture is somewhat funnel-shaped, and wider behind than in front; and, though the nerve is movable on its entrance into the sclerotic aperture, it is always fixed firmly at the inner surface of that aperture, where the retina commences.

The aperture in the sclerotic in front, for the cornea, is circular, and usually about $\frac{7}{16}$ths of an inch in transverse diameter, and rather less vertically, though in some individuals altogether smaller. Between the point of entrance of the optic nerve, and the attachments of the recti muscles, there are several minute apertures for the transmission of vessels and nerves to the interior. The nutrition of this tunic itself is provided for by small vessels ramifying on its surface, and sparingly continued into its substance. Its own proper vascularity does not seem to be greater than that of other fibrous structures.

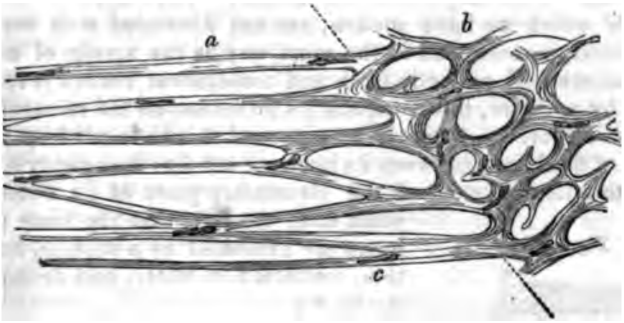
Of the Cornea.—The size and shape of this transparent part of the outer case of the eye have been already indicated. It is spherical rather than spheroidal, and its posterior surface is of parallel curvature with the anterior; so that it does not appear to be a meniscus lens, thicker in the middle, as some authors have described: this at least is the result of our careful examination. The cornea, when its concavity is filled up with the aqueous humor, is of course a powerful converger of the rays of light towards the iris, and through the pupil to the lens. Viewed from within, its circumference is exactly circular; but on the outside it generally appears wider transversely, from the sclerotic, which overlaps it on all sides, encroaching upon it rather more above and below. The cornea and sclerotic are firmly connected by continuity of texture, and cannot be disunited even by maceration. The cornea is possessed of great toughness, and will even resist a force capable of rupturing the sclerotic.

The cornea, though a beautifully transparent substance, and appearing at first sight as homogeneous as glass, is nevertheless full of elaborate structure. It is, in fact, composed of five coats or layers, clearly distinguishable from one another. These are, from before backwards, the *conjunctival layer of epithelium*, the *anterior elastic lamina*, the *cornea proper*, the *posterior elastic lamina*, and the *epithelium of the aqueous humor*, or *posterior epithelium*. The cornea, when uninflamed, contains no blood-vessels; those of the surrounding parts running back in loops, as they arrive at its border.

On the *cornea proper*, or *lamellated cornea*, the thickness and strength of the cornea mainly depend. It is a peculiar modification of the white fibrous tissue, continuous with that of the sclerotic. At their line of junction (fig. 109), the fibres, which in the sclerotic have

densely interlaced in various directions, and mingled with fibrous tissue, flatten out into a membranous form, so as to

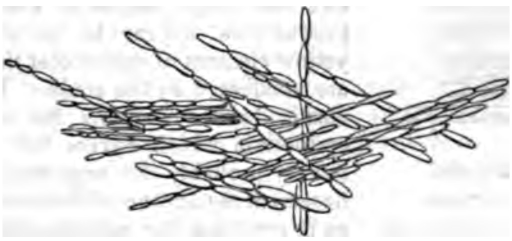
Fig. 109.



l section of the Sclerotic and Cornea, showing the continuity of their tissue between the es:—*a*. Cornea. *b*. Sclerotic. In the cornea the tubular spaces are seen cut through, e sclerotic the irregular areolæ. Cell-nuclei, as at *c*, are seen scattered throughout, rene plain by acetic acid. Magnified 320 diameters.

in the main the curvatures of the surfaces of the cornea, and stitute a series of more than sixty lamellæ, intimately united to other by very numerous processes of similar structure, passing ne to the other, and making it impossible to trace any one over even a small portion of the cornea. The resulting which in the sclerotic are irregular, and on all sides open, are ted in the cornea into tubular spaces, which have a very sinarrangement, hitherto undescribed. They lie in superposed the contiguous ones of the same plane being for the most part l, but crossing those of the neighbouring planes at an angle, dom communicating with them (fig. 110). The arrangement

Fig. 110.

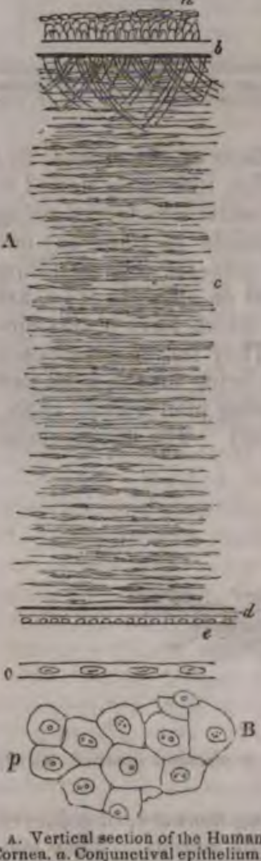


f the Cornea Proper, as shown in the eye of the Ox by mercurial injection. Slightly

e of these tubes can be shown by driving mercury, or coloured air, into a small puncture made in the cornea. They may shown under a high power by moistening a thin section of a ornea, and opening it out by needles. The tissue forming the of these tubes is membranous rather than fibrous, though with t glasses a fibrous striation may be frequently seen, both in the separating the different series of tubes, and in that dividing f the same layer from each other. By acetic acid, also, the

structure swells, and displays corpuscles resembling those apparent in the white fibrous tissue. Such is the lamellar structure of the cornea, which makes it so much easier to thrust an instrument horizontally than vertically into its substance. The tubes or elongated spaces of which we have spoken, are not distended with any fluid, but are merely moistened in the same way as the areolæ of ordinary areolar tissue. A perfectly fresh and transparent cornea is rendered opaque by pressure, but it regains its brilliance on the removal of the compressing force. Some have supposed this to result from the expulsion of fluid from between its laminæ; but that the opacity is owing simply to a derangement of the elementary parts of its structure is plain from the fact, that the same phenomena are exhibited by a section, however thin, immersed in water, and deranged by stretching.

Fig. 111.



A. Vertical section of the Human Cornea. *a*. Conjunctival epithelium. *b*. Anterior elastic lamina, from which there pass off a number of fibres into *c*, the layers of the cornea proper, among which the nuclei are apparent. *d*. Posterior elastic lamina. *e*. Posterior epithelium.—Magnified 80 diameters.

B. The posterior epithelium, *o*, seen in section; *p*, seen in face.—Magnified 300 diameters.

Of the anterior elastic lamina.—This is a transparent, homogeneous lamina, coextensive with the front of the cornea, and forming the anterior boundary of the cornea proper. It is a peculiar tissue, the office of which seems to be that of maintaining the exact curvature of the front of the cornea; for there pass from all parts of its posterior surface, and in particular from its edge, into the substance of the cornea proper and sclerotic, a multitude of filamentous cords, which take hold, in a very beautiful artificial manner, of the fibres and membranes of those parts, and serve to brace them and hold them in their right configuration (fig. 111, *b*). These cords, like the elastic lamina of which they are productions, appear to be allied to the yellow element of the areolar tissue. They are unaffected by the acids. The anterior elastic lamina sustains the conjunctival epithelium which covers the cornea, and is very probably the representative of the basement membrane of the mucous system, as it occupies the corresponding position in regard to the epithelium. Its thickness is about $\frac{1}{2000}$ of an inch.

The *conjunctival epithelium* of the cornea may always be obtained from a fresh eye, by gently scraping its surface. It consists of three or four layers of superposed particles, inclining to the columnar form, where they rest on the anterior elastic lamina, and becoming imbricated scales on the surface (fig. 111, *a*). In many of

arger animals this epithelium consists of a much deeper series of eated particles, and its transparency then becomes a remarkable acter.

is in this epithelium that particles driven with force against the generally lodge, and it is easily detached by the instrument used ttract them. Vessels shooting into the cornea in disease lie under nd small ulcers are formed by its destruction. In animals which their skin this lamina is shed with the cuticle of the body.

he *posterior elastic lamina* of the cornea (fig. 111, *d*) is a very membrane in which no structure can be detected. It has all the sparency of glass, and does not become opaque by maceration, ing, or the action of acids. It adheres but slightly to the cornea er, and, when peeled off, it has such a tendency to curl with its rior surface inwards, that it is difficult to retain a piece of it in an nded form. If floated in water, it exhibits a peculiar glistening e resulting from its density. It readily tears, yet is so hard that bitten through with difficulty. Its elasticity is great, and has supposed to contribute to the exact maintenance of the curvature e cornea, so necessary for correct vision. This lamina extends to the circumference of the cornea, where it becomes thinner; it ceases at the border of the iris, in a manner hereafter to be ribed.

f the epithelium of the aqueous humor.—The elastic lamina is itself l by an exceedingly delicate epithelium, which exactly resembles existing on serous membranes, (fig. 111, *e*, *o*, *p*; see also p. 129.) epithelium is probably concerned in the secretion of the aqueous r, but it does not extend over the whole surface with which that is in contact. It is probably limited to the cornea.

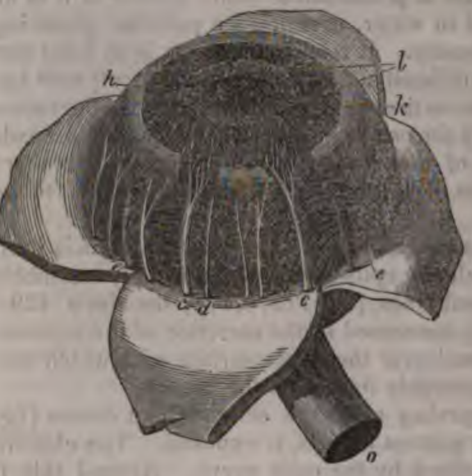
f the Choroid.—On turning aside the sclerotic and cornea (fig. , the choroid, with its process the iris, is exposed. The choroid course perforated behind by the optic nerve. Around this it res pretty firmly to the sclerotic, but in the rest of its extent very tly, and only by the medium of a slender web (*lamina fusca*), of those vessels and nerves which pass from the one coat to the . The rupture of these adhesions occasions a flocculent apnce of the choroid, and sets free some of the brown colouring r with which its structure is loaded. There is no serous cavity een the sclerotic and choroid, as some have imagined, for a true elium is wanting, though the lamina fusca contains nuclei.

e choroid, on coming up to the cornea, gives off its process the and it there adheres intimately to the sclerotic by a very narrow of white tissue—the ciliary ligament. For an eighth of an inch d this, however, it is coated by a semi-transparent band, which all distinguish as the ciliary muscle, and the fibres of which te from the cornea.

e *choroid* contains some fibrous tissue, resembling that of the otic; but it is composed principally of blood-vessels and pigment- . It has been usual to describe it as having two layers, an artend a venous; an incorrect view. It is in fact essentially a thin a of capillaries, disposed in a close network, the meshes of

which are rather smaller behind than in front. This plexus forms the inner surface of the choroid, and has been known as the *tunica Ruyschiana*. The arteries supplying it, and the veins carrying off its blood, come to it and leave it at very numerous points, but on its outer surface only, where they are so thickly arranged, side by side, as to appear to form the whole of that surface. The veins in particular are large and numerous, and disposed in beautiful curves, converging to four or five trunks, before quitting the choroid, and styled the *vasa vorticosa* (fig. 112, *e, e*). The arteries run between these, but less regularly.

Fig. 112.



Choroid and Iris, exposed by turning aside the sclerotica:—*c, c.* Ciliary nerves branching in the iris. *d.* Smaller ciliary nerve. *e, e.* Vasa vorticosa. *h.* Ciliary ligament and muscle. *k.* Converging fibres of the greater circle of the iris. *l.* Looped and knotted form of these near the pupil, with the converging fibres of the lesser circle of the iris within them. *o.* The optic nerve.—From Zinn.

Fig. 113.

Vessels of the choroid, Ciliary processes and Iris, inner surface. —*a.* Portion of the capillary network or *tunica Ruyschiana*. *b.* Ciliary processes. *c.* Portion of the iris.—From an Infant. Magnified 14 diam. After Arnold.

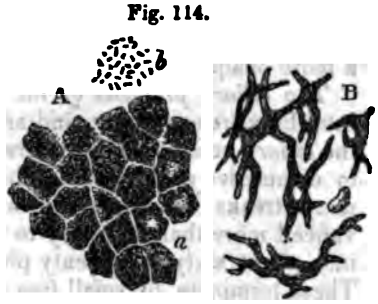
The capillary network of the inner surface is so close that there is no room for pigment-cells in its interstices; but between it and the arteries and veins, as well as among the veins themselves, there is a great abundance of colouring matter, which deeply tinges the whole thickness of the membrane.

The pigment-cells in the substance of the choroid (fig. 114, B) are extremely irregular in shape, and lie in various directions amongst the other elementary tissues. Similar ones are found in the iris, and sparingly in the anterior part of the sclerotic. They are so loaded with pigment that their nuclei are often obscured by it.

The pigmentary matter within these cells is of a sepia colour, and occurs in the form of oblong or oval grains, less than $\frac{1}{10000}$ of an inch

114, *b*). These grains exhibit molecular motion when re- m the cells, and sometimes even within the cells (p. 72). nsoluble in hot or cold he dilute mineral acids, ong acetic acid, in oil, nd ether; but are dis- ter long digestion, by uor potassæ. The ash of common salt, lime, of lime, and oxide of *lin and Berzelius*). os the colouring matter t, not only in the eyes, er organs in which it xists. The eyes have tly a pink appearance, hiefly from the blood in d and iris.

Fig. 114.



A. Choroidal Epithelium, with the cells filled with pigment, except at *a*, where the nuclei are visible. The irregularity of the pigment-cells is seen. *b*. Grains of pigment.
B. Pigment-cells from the substance of the Choroid. A detached nucleus is seen.—Magnified 320 diameters.

Choroidal Epithelium.— ner surface of the choroid, within the capillary network, ing slightly to it, is an epithelium, consisting of a single ucleated particles, of a pentagonal or hexagonal shape, filled ent. This was first particularly described by Mr. Wharton o termed it the *membrane of the black pigment*. In using , it must be remembered that the colouring matter is not this epithelium; and that this epithelium exists without front of the tapetum lucidum of animals; and also that it without pigment, in albinos, as was first pointed out by Hence the presence of pigment in its cells is a secondary The nuclei of the cells project on the inner surface of rane. They are concealed by the pigment if it is very but in general they are visible. Both conditions are seen , A.

uadrupeds and fishes the inner surface of the choroid, in its posterior rilliant lustre, owing to the presence of a thick layer of wavy fibrous arly arranged, outside the choroidal epithelium (here colourless). This *lum* must act as a concave reflector, causing the rays of light to traverse second time, and thus, probably, increasing the visual power, particularly antity of light admitted into the eye is small.

ous fishes there is a singular vascular organ of a horse-shoe shape ap- e outer surface of the choroid, and covered by a silvery membrane. Its mperfectly made out, and its office is quite unknown. It is called the

ere is a remarkable plicated, comb-like process of the choroid, projected eous humor, and termed the *pecten*. It is a vascular membrane, and pigment; its base commencing at the entrance of the optic nerve, and hing more or less nearly to the crystalline lens. The retina does not it. No satisfactory use has yet been assigned to it. Its size and shape o considerable variety.

cription of the choroid now given refers only to that por- which corresponds to the retina, and this latter membrane line (*ora serrata*) about an eighth of an inch behind the

margin of the cornea. In front of this line, and as far as the iris, the choroid is known as the *ciliary body*, being modified to form the *ciliary processes;* and it is covered on its outer surface by a semi-transparent tissue, the *ciliary muscle*, at the anterior edge of which is a more opaque white ring, the *ciliary ligament.*

The *ciliary processes of the choroid* project as folds, or plaitings, into the vitreous humor, and are there lodged in corresponding folds, the *ciliary processes of the vitreous body.* They are seen from within to commence at the anterior border of the retina, or *ora serrata*, as mere streaks, converging towards the lens; and it is only when advanced more than half way to that body that they become projected into about sixty or seventy plaits, with subordinate ones between. These terminate by small free extremities, which slightly overlap in front the border of the lens, without touching it, being united to it through the medium of a delicate layer of the hyaloid membrane of the vitreous humor. These folds take firm hold of the vitreous humor in its front part, all round the lens. Their texture is very vascular (fig. 113, *b*) and filled with irregular pigment-cells, (which in the human eye are least numerous on the most prominent parts,) and on their inner surface is a tough colourless lamina, composed of ill-defined nucleated cells, (continuous with the border of the retina, but clearly not composed of nervous matter,) by means of which they are immediately connected with the hyaloid membrane. The strength of this connection is evinced in attempts to sever it in the recent eye. After a certain amount of decomposition has taken place, the separation is much more easy. The ciliary processes by their anterior surface, near their apex, contribute to form the posterior wall and side of the posterior chamber, and are continuous with the back of the iris. They are there free, and washed by the aqueous humor. The ciliary processes are covered, and therefore concealed, on the outside by the ciliary muscle.

The *iris* may rightly be regarded as a process of the choroid; it is continuous with it, although of a modified structure. It forms a vertical curtain stretched in the aqueous humor before the lens, and perforated for the transmission of light. It is attached all round at the junction of the sclerotic and the cornea, so near, indeed, to the latter that its anterior surface becomes continuous in the following manner with the posterior elastic lamina. This lamina near its border begins to send off from its anterior surface, or that towards the laminated cornea, a network of elastic fibres, which stretch towards the border, becoming thicker as they advance, until at length the entire thickness of the lamina is expended by being converted into them. These fibres then bend backwards from the whole circumference of the cornea, to the circumference of the front of the iris, and are there implanted, passing in this course across the rim of the anterior chamber, and through the aqueous humor. They are seen more easily in some animals than in others, forming a regular series of pillars around the anterior chamber. Behind these there is a more diffused union of the tissue of the iris with the sclerotic, by means of the ciliary ligament. The iris is continuous behind, near its border, with the

cesses, and is only free in the inner half of its extent, near where it is covered with a dense layer of pigment, and converging striæ. This posterior surface is termed *uvea.* uence of the extreme proximity of the iris to the lens, the chamber is much less capacious than the anterior, as it is f smaller diameter.

terior surface of the iris has a brilliant lustre, and is marked accurately described by Dr. Jacob, nore or less direct course towards the hese lines are important as being in- f a fibrous structure. Slender, and rous in the outer three-fourths of the (the pupil being contracted), and sed near the border by wave-like coloured lines, they unite at about inch from the pupil into a circular notted and much thicker elevations, h finally proceed a multitude of mi- ching and anastomosing filaments, reme verge of the pupil. When the ntracted, these converging fibres are when it is dilated, they are thrown s into zigzags. The pupil is nearly nd is situated rather to the inner side ntre of the iris. By the movements it is dilated or contracted, so as to e or less light to the interior; and its nder these circumstances may vary t $\frac{1}{10}$ to $\frac{1}{3}$ of an inch.

Fig. 115.

Network of yellow fibrous tissue at the border of the elastic lamina of the cornea:—*a*. Outer border, where the fibres approach the iris. At their inner end, *b*, they are lost on the elastic lamina.—Magnified 70 diameters.

rieties of colour in the eyes of dif- nals and individuals depend almost the colour of the front of the iris, elf resides chiefly in pigment-cells, its substance rather than as a layer rior surface. These cells are most irregular in shape and lie in the interstices of the more essential tissues, which obscure. The iris is consequently best examined in albino

is undoubtedly contractile, and the anatomical characters cipal tissue so nearly resemble those of unstriped muscle, be considered as a variety of that tissue. Its fibres are h nuclei which are rather rounded than those of unstriped d more loosely attached to the contractile material. The direction taken by the fibres is towards the pupil, although nore or less meandering and interlacing in this course. ear the pupil, they appear to join, and form indistinct arches. nstances it is easy to detect a set of circular fibres, either nto a principal bundle near the pupil or more diffused, but ing in front of the others. These seem to answer to the res of the bird's iris, which are of the striped variety, and

occupy the front of the membrane. There may also be usually distinguished in the very thin margin of the pupil an arrangement of fibres more circular than radiating.

The iris is so vascular that some anatomists have considered it erectile, and have erroneously ascribed its movements to this property. But its vessels are slender and delicate, and resemble those of the unstriped muscle. They are derived chiefly from the two long ciliary arteries, which on approaching it bifurcate, and form a circle around it, whence pass inwards a great number of minute branches, which form loops near the pupillary margin.

On the anterior surface near the pupil a vascular circle marks the line from which in the fœtus the *membrana pupillaris* stretched across in front of the pupil. This membrane at that early period divides the anterior from the posterior chamber, and receives from several parts of the circular vessel last mentioned, small branches which approach the centre, and then return in arches, after inosculating sparingly across the central point. The membrana pupillaris is almost absorbed at birth.

The grayish structure coating the choroid for about an eighth of an inch behind the cornea, presents at its anterior edge a more white and opaque circle, the *ciliary ligament*, which seems to be chiefly of a fibrous character, and to connect the border of the iris firmly to the sclerotic. The plexiform tissue of the posterior elastic lamina of the cornea already noticed, adjoins this ligament, and partially blends with it.

Fig. 116.

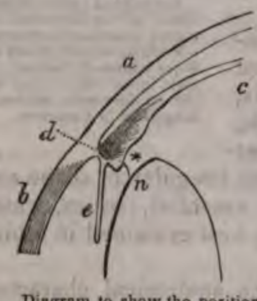


Diagram to show the position and action of the Ciliary Muscle:—*a*. Sclerotic. *b*. Cornea. *c*. Choroid, separated a little from the sclerotic. *d*. Situation of the ciliary ligament, and point from which the ciliary muscle radiates. *e*. Iris. *n*. Lens, connected with the ciliary processes by the anterior wall of the canal of Petit, the situation of which is marked by the *.—Magnified 3 diameters.

The *ciliary muscle* is that grayish, semi-transparent structure behind the ciliary ligament, and covering the outside of the ciliary body. It has been described as muscular by many of the older anatomists, especially by Porterfield, while others have assigned to it a different character. Lately it has been so regarded by Wagner and Dr. Wallace of New York, and we believe correctly. It belongs to the unstriped variety of muscle, and its fibres appear to radiate backwards from the junction of the sclerotic and cornea, and to lose themselves on the outer surface of the ciliary body. The more superficial fibres are in contact with, but scarcely adhere to, the sclerotic, and are inserted into the posterior part of the ciliary body; while the deeper ones seem to dip behind the iris to the more prominent parts of the ciliary processes which approach the lens. The ciliary muscle must have the effect of advancing the ciliary processes, and with them the lens, towards the cornea. The ciliary nerves pierce this muscle on their way to the iris, distributing to it many filaments which may be seen for the most part to cross the fibres.

The muscular nature of this structure is confirmed by its anatomy in birds, where it is largely developed, as noticed by Sir P. Crampton. We find its fibres to be of the striped variety, like the circular fibres of the iris in the same class, and to be supplied by ciliary nerves traversing the muscle in a circular direction. They likewise radiate from the cornea, at the circumference of which they are attached to the deeper layers of the cornea proper, the elastic lamina being here exceedingly thin.

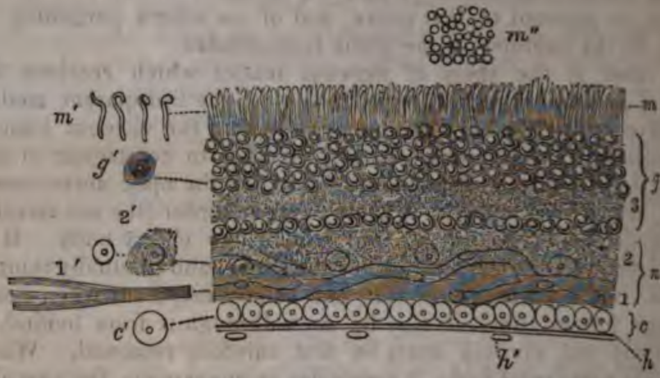
Within the choroid is the retina, which we shall describe as a structure distinct from the optic nerve, though continuous with it; reserving our account of that nerve, and of the others pertaining to the eye, till the anatomy of the globe is concluded.

The *retina* is the sheet of nervous matter which receives the images of external objects thrown upon it by the transparent media, and it is accordingly placed immediately behind the vitreous humor, the deepest of those media. It may be said to commence at the foramen in the sclerotic and choroid by which the optic nerve enters the eye, and to terminate by a finely jagged border (the *ora serrata*) at the hinder border of the striated part of the ciliary body. It is thicker behind, in the deepest part of the globe, and gradually thinner forwards. Of a pinkish-gray tint, and semi-transparent when fresh, the images formed upon it may be seen through it from behind, if the sclerotic and choroid coats be first carefully removed. When thrown into accidental folds, it resembles in appearance the vascular gray substance of the cerebral convolutions. The exquisite function performed by this nervous membrane, its expanded form and separability from other structures, have always made it an object of peculiar interest with physiologists, who have not unreasonably expected that important secrets of nervous function might be disclosed by an accurate insight into its structure. Whatever the conclusions to be drawn, it is certain that this structure is elaborate and complex, and worthy of an attentive study.

The first part of the retina to be described is the *fibrous gray layer*, which forms the immediate continuation of the optic nerve, and which is seated on its inner surface. This is a layer of fibrous character, radiating from the end of the optic nerve, and apparently consisting of the tubular fibres of that nerve deprived of their white substance; that is, being no longer tubular and white, but solid and gray, and united together more or less into a membrane. This at least seems to us to be certain, that the white substance of Schwann does not exist in the nervous substance of the retina, but ceases as the nerve perforates the sclerotic. It has been particularly described as existing in the retina of the rabbit; but the fact seems to be, that in this animal the nerve does not end in the retina till some way within the globe, for, after bifurcating and spreading out as a white streak within the choroid, the bundles of nerve-tubes suddenly lose their white lustre, and assume the appearance of the gray fibres of the layer now under consideration. These bundles, both in animals and man, may be seen to anastomose in a close plexiform manner, especially near the optic nerve, and finally constitute a thin sheet, which becomes thinner and less fibrous as we trace it forwards, until at length it can be no longer discerned. This fibrous gray layer of the retina is united to the hyaloid membrane, containing the vitreous humor, by a layer of

nucleated cells almost perfectly transparent, and sometimes very difficult of discovery on that account. It is to be remarked, that the fibrous gray layer is the only nervous element of the retina existing over the extremity of the optic nerve where it enters the globe—a spot incapable of vision. Immediately around this spot, the other

Fig. 117.



Vertical section of the Human Retina and Hyaloid Membrane. *h.* Hyaloid membrane. *h'.* Nuclei on its inner surface. *c.* Layer of transparent cells, connecting the hyaloid and retina. *c'.* Separate cell enlarged by imbibition of water. *n.* Gray nervous layer, with its capillaries. 1. Its fibrous lamina. 2. Its vesicular lamina. 1'. Shred of fibrous lamina detached. 2'. Vesicle and nucleus detached. *g.* Granular layer. 3. Light lamina frequently seen. *g'.* Detached nucleated particle of the granular layer. *m.* Jacob's membrane. *m'.* Appearances of its particles, when detached. *m''.* Its outer surface. Magnified 320 diameters.

layers commence which have now to be described, and the first of these is the *vesicular gray layer*. This layer is on the outer surface of the fibrous layer, and so intimately blended with it, that it might almost seem as if the fibres successively terminated in it. The vesicular layer is thicker behind, and gradually thinner forwards. It very accurately corresponds with the vesicular matter of the convolutions of the cerebrum, consisting of a finely granular matrix with interspersed very delicate vesicles, furnished with pellucid globular nuclei of characteristic appearance.

The blood-vessels of the retina, which are thickly distributed, belong solely to the fibrous and vesicular layers now mentioned. The central artery of the retina, after entering the globe in the axis of the optic nerve, sends four or five radiating branches, which almost immediately perforate the fibrous layer and spread out in a beautifully arborescent manner, as a capillary network in the substance of the vesicular stratum. After slight maceration, it is easy to wash the nervous material out of the meshes of the vessels; and they then form a vascular layer, but which it is hardly correct to describe as a distinct lamina of the retina. They are merely the nutrient vessels of the part, and are the representative of the close network of the gray substance of the cerebral convolutions. Their wall is a diaphanous membrane with nuclei projecting at intervals, and the meshes average $\frac{1}{400}$ of an inch diameter.

Behind the vesicular gray layer is the *granular layer*, a term we shall apply to it, because it seems to consist of a close aggregation

;ranules, which refract the light more powerfully than the ng parts, and have scarcely any appearance of intervening :y might be regarded perhaps as analogous to the nuclei of nuch resemble a layer of granules in the substance of some :bral convolutions, and of the laminæ of the cerebellum. nade more evident by acetic acid. This layer is divided f which the inner is much the narrower, by a *pale stratum*, only be seen by very careful manipulation.

outside of the granular layer is that remarkable lamina, the name of its discoverer, *ana Jacobi*. It consists of d rods, placed uprightly, nd inwards, the thick out- d it is very easily detached est of the retina, when the removed, so as to float as reds, visible to the naked water in which the eye is The rods have a tendency : from one another when vater, and the club-shaped are then often seen to be a sudden bending back of ike a crook, which may be s opened out. Interspersed

Fig. 118.

Outer surface of the Retina, showing the membrane of Jacob, partially detached. After Jacob.

rods are seen on the outer surface a number of clear spaces, transparent cells were disseminated among them. This the connecting medium between the retina and the cho- ielium.

ıen before stated that the optic nerve pierces the sclerotic ie retina about an eighth of an inch on the inner side of the eye. Precisely in this axis, the retina is of a decidedly ıur in a roundish spot of about $\frac{1}{12}$ of an inch diameter, r its discoverer, the *yellow spot of Sœmmerring*. This only in man and the monkey among mammalia, but an ɔart has been found by Dr. Knox in reptiles. It has been ıy some as a fold, by others as a foramen in the retina, and il examinations we should speak of it as a small mound, ın of the retina towards the vitreous humor, with a minute the summit. On removing the sclerotic and choroid with care, the interior of the globe can be seen from the out- ;h this hole; and yet the membrane of Jacob appears to be over it. On examining the structure of the retina about spot, from within, the fibrous expansion of the optic nerve retching in every other direction to a much greater dis- ıot be traced quite up to the spot itself. Nucleated cells elongated meshes of the fibrous plexus already described, gth the fibres disappear, and the closely set cells seem to vhole surface of the spot. The gradual subsidence of the ; interstices of the cells we have distinctly seen. As for

the colouring matter, it is not in grains of pigment, but stai
several tissues, and soon disappears in water. The use of the y
spot is unknown. It is interesting to obse
connection with the perfection of vision o
spot, that the principal branches of the
and vein of the retina, above and below,
round it at a distance, going, as it were,
their course to avoid it, so that only ca
vessels are found in its immediate vicinit

Fig. 119.

The yellow spot of the Retina occupying the axis of the eye; and the entrance of the optic nerve, with the arteria centralis retinæ on the inner side of the axis.—After Sœmmerring.

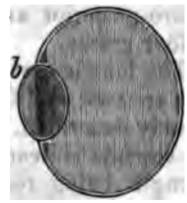
It now remains to describe the trans
media which occupy the interior of the b
the eye.

The *vitreous body*, lying in the conca
the retina, and filling all but about the a
fifth of the globe, has, when entire, the c
ence of soft jelly. It consists of an excee
fine and close, but perfectly transparent web of fibrous tissu
meshes of which are exceedingly small, and contain an aqueous
If the tissue be cut into, the water will slowly drain off, showi
continuity of the cells with one another; and the manner in
they are constructed by interlacing fibres may be very plainl
with a high power near the ciliary processes, in the vicinity of
these fibres are particularly strong. The whole vitreous b
bounded by or contained in an envelop of extremely thin ho
neous membrane, having corpuscles or cell-nuclei on its inner su
where the fibrous tissue is attached (fig. 117, *h*, *h'*). It would p
be convenient to restrict the term *hyaloid membrane* to this en
Where the retina extends, that is, as far as the ciliary bod
hyaloid membrane is in contact with its inner surface, and
to it by an extremely *transparent layer of cells*, which often r
invisible until swollen by the imbibition of water (fig. 117,
These cells serve merely as a bond of connection between the h
membrane and the fibrous lamina of the retina. Between the
rior border of the retina and the border of the lens, the vitreous
is accurately adapted to the ciliary striæ and processes of the ch
and presents a series of plaitings precisely similar to those of th
cesses themselves, and termed the *ciliary processes of the vitreous*
Collectively they form a circle called *zonula ciliaris*, or, *zone of*
The two structures are in a manner dovetailed into one another
so intimate is their union, that, when the processes of the choro
drawn away from the vitreous body, some of their pigment is
rally left adhering to the processes of the latter.

In the centre of its anterior surface, in a space nearly correspo
to the area between the points of the ciliary processes, the vi
body is hollowed out to receive the crystalline lens. This la
contained in, or bounded by, a perfectly closed capsule, compo
a tissue exactly resembling the elastic lamina of the cornea a
described. To the whole posterior surface of this capsule, an
very narrow circumferential portion of its anterior surface, the
structure of the vitreous body is firmly attached; the hyaloid

e itself not passing behind the lens, but adhering to the capsule ound a little in front of its rim, after crossing the interval sepa- ıg the tips of the ciliary processes of the choroid from the lens. s the rim of the lens is not exactly at the surface of the vitreous y, but buried slightly within it, and over- ed a little by it. All round the rim of the , there is a cavity in the vitreous body, ex- ling under the circle of the ciliary processes ne latter, and termed the *canal of Petit* (fig. , and fig. 116*). The hyaloid membrane stituting these ciliary processes forms the rior wall of this canal, which, by its adhe- ı to the ciliary processes of the choroid, is ject to be drawn forwards by the contraction he ciliary muscle already described (p. 412). en this occurs, the lens also is advanced, in sequence of the union of this anterior wall he hyaloid to its anterior surface near the . Were the canal of Petit wanting, the ıry muscle would act rather on the vitreous body around the lens, ı on the lens itself. Its existence may be easily shown by filling ith mercury or air, through an artificial orifice in its anterior wall. injected fluid fills out the plaitings of the ciliary processes.

Fig. 120.



Position of the Lens in the vitreous humor, shown by an imaginary section. The dark triangular space on each side of the lens is intended to indicate the position of the canal of Petit.—After Arnold.

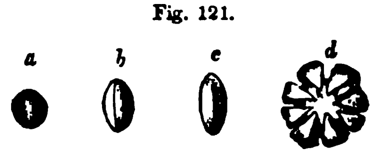
he refracting index of the vitreous body is about 1·339, that of er being 1·336, so that the difference between them is very trifling, may be referred in part to the transparent fibrous tissue. Its mical constitution, according to Berzelius, is as follows:

Water	98·40
Chloride of Sodium, with extractive matter	1·42
Albumen	·18
	100·00

ı early life the vitreous body gives passage by a canal to a branch ne central artery of the retina to the back of the lens; and in large nals, though not in man, this appears to supply some branches to vitreous body itself even in the adult state.

he *crystalline*, as already mentioned, is a double convex lens; its surfaces are of unequal curvature, the posterior being the more vex. In the adult the differ- is nearly as 4 to 3, but it is e to some variety in different ects. Chossat has observed the curvatures of the lens in ox are ellipsoids of revolu- round the lesser axis, but her they are so in man is not mined: the subject is one difficult of investigation.

Fig. 121.



Human Lens:—*a*. At birth. *b*. At six years old. *c* Adult. *d*. Hardened in spirit, and partially separated into segments.—After Sommerring.

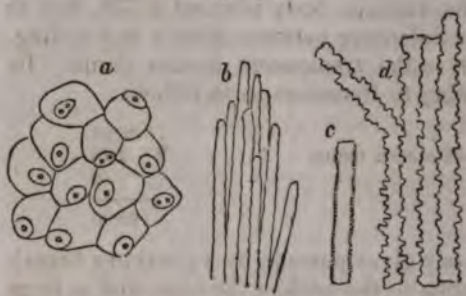
lens alters its shape with age; being in the fœtus more spherical, flattened in childhood, and still more so in advanced life. In

infancy it projects into the aqueous humor so as to touch the i in old age there is a space intervening. The lens also varies sistence with age; being very soft at an early period, very declining years. At no epoch of life, however, is it of unifo sistence throughout; being always denser and firmer from inwards. In the adult its diameter is from $\frac{1}{3}$ to $\frac{3}{8}$ of an inch, antero-posterior axis about $\frac{1}{5}$ to $\frac{1}{6}$ of an inch. It weighs fro to four grains.

The lens is divided into *capsule* and *body*. The manner i it is encased and fixed by the capsule in the vitreous body, h already described. It only remains to add, that the anterior the capsule is nearly four times thicker than the posterior; strength being required in front, where the surface is free aqueous humor, than behind, where it is adherent to the tissu vitreous body. The diminution in thickness does not occur a at the rim of the lens, but commences gradually on the surface near the rim, at a line corresponding to the attach the anterior wall of the canal of Petit. The capsule is p closed, and cannot allow of the passage of either vessel or n its interior.

The *body* of the lens is constructed in a manner calculated t admiration. Its ficies, by which i into contact with t sule, consists of of extremely tran nucleated cells sented in fig. These cells form ganized connecti dium between th and capsule of th and there is no int not occupied by After death the soon become load water (absorbed probably by the

Fig. 122



a. Cells connecting the body of the lens to its capsule (human). *b.* Fibres of the lens, with slightly sinuous edges (human). *c.* Ditto from the Ox, with finely serrated edges. *d.* Ditto from the Cod; the teeth much coarser.—Magnified 320 diameters.

from the aqueous humor), which is the *aqua Morgagni*, th have supposed to exist naturally between the capsule and bod lens near its border.

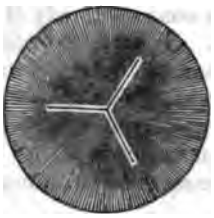
The body of the lens is composed of fibres superimposed another, and united side to side in laminæ, of which many h must exist. The mode of arrangement of the fibres is, howeve artificial than this. In the mammalia in general there are vi the front surface, when the lens has slightly lost its transp three lines, extending from the centre two-thirds to the bor dividing it into three equal parts: and on the opposite surfa similar lines exist, having an intermediate position. From these lines the fibres pass from surface to surface. Thus, a fi

ds from the centre in front, advances midway between two of the
s over the border, and comes on the opposite surface to the ex-
nity of one of the lines. Others pass from the extremities of the
s in front, and are lost in the centre behind. And the rest of the
erficial plane are intermediate to these, and as nearly parallel as
ir curved course will allow. If we now consider that these lines
the surface are but the edges of planes which dip to the centre,
l afford points of divergence and concourse for all the fibres deep
well as superficial, we shall readily comprehend what may at first
ht seem an intricate structure. This arrangement was known to

Fig. 123.

Lens, hardened in spirit and partially divided along the three interior planes, as well as into lamellæ.—Magnified 3½ diameters. After Arnold.

Fig. 124.



Triple line on the surface of the Lens of the Sheep, with the radiation of the fibres indicated. The interspace between the radiating lines at the circumference of this figure would each include about a hundred fibres. —Magnified 3 diameters.

uwenhoeck, and has been shown by Sir D. Brewster to present
eties in different classes of animals. In the human lens we find
tripartite division is seen imperfectly, and only in the centre; for
three primary diverging lines bifurcate again and again, and with
iderable irregularity, so that the ultimate subdivision is into from
ve to sixteen parts in the adult, but only from four to six in the
s.

) the account now given may be added, that as the fibres are
er in proportion as they are more internal, so do they appear
wer, more cylindrical, solid, and intimately united to each
, as we trace the structure inwards. The superficial fibres are
ned according to the surface they answer to; and of all it may
aid, that they are narrower towards their extremities, as their
gement renders necessary. The edges of the fibres in fishes are
beautifully toothed, and dovetailed together, as Sir D. Brewster
ed out (fig. 122, *d*); and something similar may be detected in
ore superficial fibres of the lens of the larger mammalia, and in
But the deepest fibres present scarcely any trace of this ele-
structure. Near the tripartite division of the lens the fibres are
united than elsewhere, and appear more or less consolidated
her. The average thickness of the fibres in man is about $\frac{1}{5000}$ of
ch.

e increasing density of the lens towards its centre is attended
an increase of the refracting power, designed to augment the

convergence of the central rays of the transmitted pencils in their course through the lens, and thus to bring them to the same focus with the circumferential rays. Sir D. Brewster states the refracting power of the lens at its surface to be 1·3767, and at the centre 1·3990.

The lens, during its development, has a very copious distribution of blood to the outer surface of its capsule, from two sources. The central artery of the retina sends a vessel through the vitreous humor to the centre of its posterior surface, which branches into a radiating series of capillaries investing it as far as the border, where they anastomose with vessels derived from the ciliary processes, which proceed some way over the front of the capsule, and return in loops. None of these vessels continue after the lens has attained to maturity.

The lens consists chiefly of albumen, and becomes hard and opaque by boiling. The central parts evidently contain a smaller proportion of water than the outer layers, which merely become flocculent by the action of heat. The fibrous and lamellar structure is more easily seen when thus rendered opaque, and it then separates more easily along the triple or multiple planes already indicated. Berzelius states the precise chemical constitution of the lens to be as follows:

Water	58·
Albumen	35·9
Alcoholic extract, with salts	2·4
Watery extract	1·3
Membrane	2·4
	100·0

The *aqueous humor*, as its name imports, is very nearly pure water, containing, according to Berzelius, less than a fiftieth of its weight of other matters, of which more than half is chloride of sodium, and the rest extractive, soluble either in water or alcohol.

It fills up the space between the cornea and lens—a space divided into two cavities by the membrana pupillaris in the fœtus, and still partially divided by the iris into an *anterior* and *posterior chamber*, continuous through the pupil. The anterior, though small, is much larger than the posterior, and is bounded by the cornea in front, the iris behind, and a portion of the ciliary ligament at its circumference. The posterior is bounded by the iris in front, the lens and a narrow circle of hyaloid membrane behind, as well as by the ciliary processes which slope towards the iris, and thus limit the lateral dimensions of the chamber. It is very easy to imagine the existence of a lining membrane to this cavity of the aqueous humor, such as would form a closed sac, and answer to the serous structures; and a *membrane of the aqueous humor* has accordingly been described by several anatomists. But the most careful observation fails to detect any such *serous sac*, though the posterior epithelium of the cornea (p. 407) closely resembles that of serous surfaces. No epithelium exists in front of the iris, and certainly none is present on the anterior surface of the lens: this we can aver from repeated examination. On the posterior surface of the iris, however, there seems to be a pigmentary membrane.

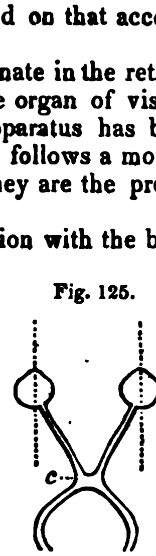
Of the Optic Nerves, and their central connections.—The second

rves is devoted to the sense of sight, and on that account ed the name of Optic Nerves.

rked manner in which these nerves terminate in the retinæ, nt relation in size between them and the organ of vision, y which they suffer when the visual apparatus has been the impairment or loss of vision which follows a morbid iem, place it beyond all question that they are the proper s of visual impressions to the sensorium.

:ic nerves form a most extensive connection with the brain ie *optic tracts*. The optic tracts are ıed bands of nervous matter, which om the posterior and superior surface ›ocephale (the region of the quadrige- ›rcles) forwards along the inferior sur- :h crus cerebri, and after passing in a urse (concave inwards) along the base n, unite in front of the tuber cinereum lary bodies, and form a very intimate which is called the *chiasma* or com- the optic nerves.

Fig. 125.



Plan of the optic nerves on a small scale, showing their divergence from the chiasma, c, and their junction with the globe, on the inner side of the axis of the humors.

ıis chiasma the optic nerves spring, ;e as they pass forwards into the orbits ıe optic foramina. This point may upon, therefore, as their origin. To l, however, more exactly their relation n, it will be necessary to trace the connections of the optic l to inquire into the structure of the chiasma.

ıg each optic tract back from the chiasma, we find that it a pretty close connection with the locus perforatus on the ıd with the tuber cinereum on the inside. Whether any of spring from the tuber cinereum is matter of great uncer- 'urther back the optic tract adheres by its outer margin to erebri, and is concealed by the middle lobe of the brain. urse it expands considerably, and at the posterior edge of ›rebri it forms intimate connections with certain gangliform the brain. First, we observe its connection with the ex- iculate body, a small prominent tubercle of darker colour urrounding parts, and situate at the posterior margin of the :ems to involve the outermost fibres of the tract, as a gan- from it a band of fibres is continued back to the posterior of igeminal bodies. Beneath the posterior extremity of the mus the innermost fibres of the tract form a connection with nilar body, the internal geniculate body, from which fibres ued backwards to the anterior of the corpora quadrigemina. , thus, appear to divide, each into two bands: of which the after passing through the external geniculate body, reaches and the inner one, similarly related to the internal geni- y, reaches the nates.

ic tracts are connected with the optic thalami chiefly *through* 'ate bodies. Each tract adheres to the outer side of its cor-

responding thalamus for some distance, but whether any fibres sink into it is not determined. In the horse, dog, sheep, and monkey, this arrangement is very conspicuous, as the greater portion of the fibres of the tract expands over the internal geniculate body, which is incorporated with the posterior extremity of the thalamus. The diameter of the tubules of the optic tracts we have found to vary from $\frac{1}{1700}$ to $\frac{1}{5000}$ of an inch.

The chiasma results from the junction of the optic tracts in front of, and inferior to, the tuber cinereum. The fibres which form the inner margin of each tract, *p*, are continued across from one side of the brain to the other, and form no connection with the optic nerves, and exist where those nerves do not exist, as in the mole. These fibres may be regarded as commissural between the thalami of opposite sides. The remaining fibres of the tracts go to form the optic nerves; the central ones pass into the nerve of the opposite side, decussating the similar fibres of the other tract; and the outermost fibres, *much fewer* in number than the central ones, pass to the optic nerve of the same side.

Fig. 126.

Course of fibres in the chiasma, as exhibited by tearing off the superficial bundles from a specimen hardened in spirit. *a*. Anterior fibres, commissural between the two retinæ. *p*. Posterior fibres, commissural between the thalami. *a'*, *p'*. Diagram of the preceeding.

This disposition of the fibres of the chiasma may be demonstrated on a specimen which has been sufficiently hardened in spirit, by tearing the fibres in their proper direction after the removal of the neurilemma. By such a procedure it may be shown that each optic nerve derives its principal fibres from the tract of the opposite side, and only a few fibres from those of its own side.

The existence of such a decussation of fibres in the chiasma is, moreover, rendered highly probable by the strong indications of most extensive decussation, resembling that of the anterior pyramids, in some of the large carnivorous birds, and also in the crossing of the entire optic nerves in some of the osseous fishes, the cod for example.

In the common domestic quadrupeds the decussation of the fibres is not to be made out so plainly, probably from its being more complicated. The chiasma somewhat resembles a knotted union of the two tracts, which is dense and firm in structure.

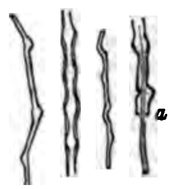
The optic nerves appear also to be connected by fibres, forming the anterior border of the chiasma, and which may be regarded as commissural between the two retinæ (*a*, fig. 126).

From the quadrigeminal tubercles to the chiasma, nerve-tubes, mostly of large size, are visible by the microscope in the tracts. In the chiasma and the optic nerves, the fibres, although very variable in size, are so closely connected together that it is exceedingly difficult to separate them. They seem to be collected into numerous small bundles, having an intricate plexiform interlacement within the

sheath. Each bundle is surrounded by a firm but dense ıma, and thus it is impossible by the ordinary means of mani- to separate a portion of the nerve of sufficient delicacy to any considerable length of its fibres.

ɜ and character of the fibres may be d by examining portions of them roject from the margin of the piece. optic nerve is abundantly supplied ɔillaries, which form a network with d meshes in its substance. A little the globe, it receives from the oph- artery a branch, before alluded to, ia centralis retinæ, which penetrates is, along which it runs to the inferior ye, in a canal of fibrous tissue. This then radiates to supply the retina, he fœtus sends forwards a twig to the t is accompanied everywhere by cor- ing veins.

Fig. 127.



Fragments of Nerve Tubules from the human optic nerve, of various sizes and varicose. At *a* the central axis projects beyond the white substance at a broken extremity.—Magn. 320 diam.

nerves are distributed to the eye, which are connected with ient and other actions of the eyeball. These are derived from halmic division of the fifth, from the third pair, and from the etic. It is remarkable, however, that all these nerves, with eptions, between their origin and their distribution in the the eye, meet in a small ganglion situated on the outer side ɔtic nerve, called the *ophthalmic* or *lenticular* ganglion. This usually considered a portion of the cephalic division of the etic; it is connected with the superior cervical ganglion by a nch which ascends from the carotid plexus along the carotid nd enters the orbit. A long nerve from the nasal branch of halmic division of the fifth also joins this ganglion at its supe- posterior angle, and a short thick branch from the third nerve ganglion at its inferior posterior angle. From the anterior f the ganglion thus formed, proceed two bundles of delicate from twelve to sixteen in number (*ciliary nerves*), which, after pierced the sclerotic at its posterior third, pass between that d the choroid, and are distributed chiefly to the ciliary muscle but also to the cornea.

the nasal branch of the ophthalmic there proceed two long called *long ciliary nerves*, which do not form any connection ophthalmic ganglion. These nerves pass off in company, separate from each other, one going to the inner, the other ɔuter side of the eyeball; they penetrate the sclerotic, and ıny the other ciliary nerves in their distribution to the ciliary ınd iris.

ye is moved by six *muscles*, four straight and two oblique. ıer arise from the margin of the optic foramen, at the apex bit, and are inserted into the sclerotic near the cornea, above, nd on each side. The superior oblique arises with the recti, ts direction changed by a pulley of fibrous tissue at the upper

and inner part of the margin of the orbit; whence it passes backwards, outwards, and downwards, under the superior rectus muscle to the sclerotic behind the transverse median plane of the globe, between the superior and external recti. The inferior oblique arises from the lower part of the margin of the orbit, about its inner third, and passing backwards, outwards, and upwards, under the inferior rectus, is inserted into the sclerotic, near, but beneath the superior oblique. The action of the recti muscles is obvious: when used in concert, they fix the eyeball; when singly, they turn it towards their respective sides. The globe, besides being imbedded in fat, is suspended or slung in a capsule of fibrous tissue, with which it is in immediate contact. This is attached in front to the tarsal cartilages, and is prolonged backwards over the globe and optic nerve, after being perforated by the muscles. Mr. O'Ferrall, who has lately directed attention to this fibrous structure, has termed it the *tunica vaginalis oculi.* It is important, as furnishing support to the eyeball under muscular movements. The recti muscles are supplied by the third pair of nerves, except the external, which receives the sixth. The oblique muscles antagonize the recti, and must in addition, if acting together, draw the globe inwards, and converge the axes of the eyes. The superior oblique, if alone, would most probably direct the front of the eye downwards and outwards, and the inferior oblique upwards and inwards; but on these points much difference of opinion still prevails. The former is supplied by the fourth pair, the latter by the branch of the third that gives the motor fibres to the ophthalmic or lenticular ganglion, from which the ciliary muscle and iris receive their nerves. And, in connection with the latter arrangement, it is interesting to remark that the pupil contracts when the eyes are directed inwards and upwards, and generally also in the adjustment for near vision, which is attended with a convergence of the optic axes. During sleep the eyes are usually turned inwards and upwards, and the pupil is contracted—actions produced through the medium of the inferior division of the third pair supplying the inferior oblique and iris. The iris is evidently involuntary in its movements; it contracts only in obedience to this stimulus of light upon the retina, or when the eye is turned upwards and inwards.

The *eyelids* are exquisitely adapted to shield the eye from too strong light, and to protect its anterior surface from the contact of hurtful substances. In the upper lid, which is much larger and more moveable than the lower, there is a thin sheet of cartilage, curved to fit the front of the eye, and to facilitate its gliding motion over the globe. To the posterior convex border of this *tarsal cartilage* the levator palpebræ muscle is attached, which thus serves to elevate the whole lid. The lower lid possesses a very narrow slip of cartilage, which meets the upper at each side through the medium of fibrous tissue, which, at the outer angle of the eye is attached loosely to the malar bone, and at the inner angle forms a tendinous cord, the *tendo oculi,* about a quarter of an inch long, which passes horizontally to be fixed to the nasal process of the superior maxillary bone. This latter is the principal attachment of the eyelids. The eyelids enclose the

bicularis muscle between the skin and their cartilages. Its fibres a in curves from the lower border of the tendo-oculi and neighuring part of the border of the orbit, encircling the eye and formg a thin layer under the skin, both of the lids, cheek, and brow, d returning to the upper border of the tendo-oculi. They are suped by the portio dura, and perhaps by some fibres of the fifth nerve, d act generally in answer to the stimulus of air or foreign particles the fifth nerve in the conjunctiva, as well as of a too strong light on the retina. The will exerts a limited power over the orbicula-, but is quite unable to restrain its action when sufficiently excited the before-named stimuli. The entire muscle consists of striped res. The lids are further armed along their free margin by the licate curved hairs, called the lashes. These intercept the entry of reign particles directed against the eye, and assist in defending the gan from excess of light.

At the border of the eyelids, the skin becomes continuous with their ucous lining, termed the *conjunctiva*. This membrane lies upon e tarsal cartilages, and is then reflected over the front of the globe, here it has been already in part described with the cornea. Beveen the cartilages and the conjunctiva, and partially imbedded in e former, are the ***Meibo-ian glands***, which may be en through the conjunctiva gure 128). Each gland nsists of a series of folli-es, arranged upon an elon-ated common duct, which npties itself on the border f the lid. They consist of basement membrane and a epithelium (fig. 129); e latter contains sebaceous atter in its cells, and is in ontinual course of forma-on. Its particles, when lly developed, are thrust rward along the duct, and nstitute the secretion. The e of the Meibomian glands obviously to prevent ad-sion of the lids; and their rangement side by side, so as to form an even layer, adapts them to e surface of the globe, over which they are being constantly moved. ey are a variety of the cutaneous sebaceous glands, which they emble in every particular except shape. At the inner canthus is arge-sized sebaceous gland, covered with mucous membrane, and ually termed the *caruncle* (fig. 130).

Fig. 128.

View of the conjunctival surface of the Eyelids. The Meibomian glands are seen running towards the edges of the lids:—*l*. The lachrymal gland removed with the lids. *d*. Orifices of its seven ducts on the conjunctiva. At the inner extremity of the borders of the lids the orifices of the canaliculi (puncta lachrymalia) are seen. *o*. *o*. Orbicularis muscle beyond the lids.—From Sœmmerring.

The conjunctiva of the lids presents on its free surface a minute pillary structure, probably connected with the exquisite sensibility ich renders this membrane so valuable a covering to the eye. In

the disease termed *granular lids*, these papillæ are hypertrophied. To the sclerotic coat the conjunctiva is loosely attached by lax areolar tissue in which numerous tortuous vessels lie.

The front of the eye is irrigated by the lachrymal fluid secreted by the gland of that name. This gland is placed within the orbit, under cover of the external angular process of the frontal bone, and is about the size represented in fig. 128, *l*. In appearance and structure it has much similarity to the salivary glands; its ultimate parts being vesicular. Its ducts, about seven in number, open on the conjunctiva, at its upper and outer part near its reflexion on to the globe, and are arranged in a row, so as to disperse their secretion over the membrane (fig. 128, *d*). The constant motion of the upper lid facilitates the distribution of the fluid, which thus streams continually over the

Fig. 129.

One of the Meibomian glands of a Fœtus of five and a half months:—*a*. Basement membrane of the follicles. *b*. Epithelium constituting the secretion. *c*. Orifice of the common duct.—From a specimen prepared by Dr. Goodfellow. Magn. 30 diameters.

Fig. 130.

Anterior view of the Lachrymal Apparatus—7. The lachrymal gland in outline. At the inner canthus are the puncta, 1. and canaliculi, 2. with the caruncula between them. The lachrymal sac forms the upper third of the vertical tube, 5, 6, and the nasal duct the remainder. These parts are separated within by a fold of the lining membrane.

front of the eye, and carries off any extraneous particles that may have found their way into it. The fluid is then conducted into the nostril through a singular system of channels, lined by mucous membrane, continuous between that of the eye and nose. Near the inner end of the border of each tarsus there is an orifice, a little prominent, and projecting slightly backwards, so as not to be obstructed when the lids are closed. These are the *puncta lachrymalia* (figs. 128 and 130). They lead by two ducts (*canaliculi*), into the *lachrymal sac*, a

rmed by the lachrymal and superior maxillary bones, com-
r fibrous membrane. This is continued, under the name of
t, into the inferior meatus of the nose, where it opens under
the lower spongy bone. A fold of mucous membrane usually
s orifice.

: *phenomena of Vision.**—The consideration of the changes

illowing laws affecting the passage of rays of light through transparent
arious density ought to be kept steadily in view by the student of the phy-
rision.

of light, in its passage from a rare into a dense medium, is bent, or, in
guage, refracted, *towards* the perpendicular to the point of incidence, if it
ly upon the surface of the latter medium. The direction of the ray, there-
red in the dense medium. The degree of this refraction depends partly
lensity of the medium, and partly upon the angle at which the ray falls
e angle of incidence). If the ray of light fall upon the transparent surface
gles to it, it will pass through it without undergoing any change in its di-

ray pass from a dense to a rare medium, it will be refracted *from* the per-
to the point of incidence.

bvious, from what has been stated, that the incident and refracted ray will
on different sides of the perpendicular.

cases where rays of light pass from one transparent medium to another, a
tion of them is reflected at the surface of each new medium. If, therefore,
through many different media in succession, much of it will be completely
om its original direction by *reflexion*.

ieral, the greater the specific gravity of a body, the greater is its refracting

encil of rays diverging from a luminous point fall directly upon the surface
x lens, they will not all be equally refracted. The central ray will pass
changed in its course. Those nearest the centre will be least refracted;
distant from it (which consequently fall with the greatest obliquity upon
of the refracting medium) will be most refracted.

e emergence of the rays of light from a bi-convex lens into air, or any
um less dense than the lens itself, each ray will be bent away from the
ilar to the point of emergence. The effect of this is to cause a converg-
the emerging rays towards the central ray; at this point of convergence,
n image of the luminous point from which the rays originally passed is

point of convergence, or focus, varies as to its distance from the surface of
, according to the refracting power of the lens, the amount of curvature of
, and the distance of the luminous body. Its distance constitutes the focal
istance of a lens.

isequence of the unequal refraction of rays passing through a convex
cus of convergence of the central rays is more distant from the surface of
an that of the peripheral rays. Hence the image formed at the focus of
in some degree indistinct at its edges. The imperfection is due to what
lly called *spherical aberration;* and it can be counteracted only by inter-
passage of the circumferential rays, or by employing such a combination
s will establish a just proportion between the refraction of the central and
rays. This aberration is liable to occur in all forms of lenses, whether
concave.

te light is compound, and may be analyzed by passing a beam of sunlight
prism. The solar *spectrum* thus formed on a surface opposite the prism is
of bands of different colours insensibly passing into each other, which are,
from above, violet, indigo, blue, green, yellow, orange, and red. Of these
loured rays, that which is most bent from the original direction of the solar
e violet, and the red is the least refracted. It is owing, therefore, to this
frangibility of the different kinds of simple light that we are enabled to
white light by its transmission through a prism.

e different coloured rays which have emerged from the prism be allowed
a second similar prism, held in a reversed position, they will on their
unite to form white light again.

produced in the rays of light passing through a double convex lens explains, to a great degree, the phenomena resulting from the passage of the rays through the dioptric media of the eye.

A ray, falling on the surface of such a lens, is bent towards the perpendicular to the point of incidence, and continues in that direction to the opposite surface of the lens. It then emerges from the lens, and, in thus passing from a dense to a rare medium, it is bent from the perpendicular to the point of emergence. It can thus be shown that the component rays of a pencil diverging from a point, will be bent towards the central ray of the pencil, or that which falls perpendicular to the convex surface, and be brought to a focus in the line of the central ray. And the several pencils of rays, proceeding from different points of an object, cross one another in traversing the lens, so that the foci to which they are respectively brought beyond the lens are in positions the reverse of those from which they set out, and the entire image is a reverse of the object.

To apply this to the eye.—If a luminous object, as the flame of a candle, be placed eight or ten inches in front of the organ, some rays fall on the sclerotic and are reflected; the more central ones fall on the cornea: some are reflected, and others pass through it, are slightly converged by it, and enter the aqueous humour, which, being probably of the same refracting power, does not alter their course. Passing onwards, some meet the iris and are absorbed or reflected by it, whilst others advance through the pupil. Thus rays, falling on a large extent of the cornea, are converged so as to fall on the lens. By the convexity of the surface of the lens, as well as by the greater density of that body towards its centre, this convergence is much increased. Lastly, by their passage into the rarer medium of the vitreous humour, the rays are further converged by the refraction of each ray from the perpendicular to the point of incidence, and the several pencils which they form are brought to as many foci in the retina. And still further, the rays from the opposite points of the luminous object, by reason of the change of direction which they undergo through these successive refractions, cross one another, (the angle of crossing being called *the visual angle*,) and thus the image of the flame on the retina appears inverted.

This inversion of the image may be exhibited by a model, representing the transparent media of the eye, with a retina of ground glass; or it may be shown on a recent eye by simply removing the opaque coats behind the retina, or in the eye of a white rabbit, after removing the muscles and areolar tissue around it.

When the retina corresponds, or nearly so, to the points of convergence of the several pencils of light, *distinct* vision of the object is obtained; and the distance for distinct vision is ordinarily about

12. The different refrangibility of the rays of simple light is another source of indistinctness in images formed by the transmission of light through lenses with curved surfaces. The images are fringed by prismatic colours. It is called technically *chromatic aberration;* and may be corrected by means analogous to those adopted for correcting *spherical aberration.* It is obviously of great importance in all optical instruments for aiding or increasing the powers of vision that they should as much as possible be free from these sources of imperfection.

inches. If that distance be increased or diminished (no change ıg produced in the eye), vision is indistinct; for when the object :moved to a greater distance from the eye, it is obvious that the ıs will be moved forwards, or will fall short of the retina; and en the object is approximated, the focus will be moved backwards eyond the retina: in both which cases the same point of the re- ı will receive rays from several points of the object. Hence it is, t when the eye is adapted to distinct vision at a distance of ten hes, we cannot distinctly see objects at a greater or less distance. m the cause of this, which has been just alluded to, however, it evident that, provided the rays unite very nearly on the retina, ion, especially of large objects, may prove sufficiently distinct, al- ugh not perfectly clear. Hence the distinction of Jurin between tinct and *perfect* vision is worthy of being borne in mind. Dis- ctness of vision will depend on the size of objects, as well as on ir distance from the eye; perfection of vision, on their distance ne.

This leads to the consideration of one of the most admirable pro- ions for the extended utility of the organ; viz., its capacity of ptation, under the influence of the will, to distinct vision at every tance beyond that of a few inches. We have the power of pro- cing some change in the eye by which its focal length is modified uit the varying angle at which rays from surrounding objects fall n it. Many different explanations have been attempted of the de in which this adaptation is effected, of which may be mentioned t of Jurin, Ramsden, and Home, that the cornea undergoes a change ts curvature, becoming more convex for near objects: and that of ı Cartes, Albinus, Hunter, and Dr. Young, who considered the ı muscular, and to possess within itself the power of changing its vature.

Others, again, ascribe this power of adaptation to the iris, the mo- s of which might, as Knox supposed, alter the curvature of the ı; or, according to Sir David Brewster, cause the lens to change lace, and come forward during contraction of the pupil. A change he position of the lens has also been supposed to occur from con- tions in the ciliary processes or zonula, and many have contended the entire eyeball may alter its relative dimensions by the action ts muscles.

: is conceivable that any of these changes, could they be proved ally to take place, might be sufficient to account for the effect; in estimating their relative value, the greatest importance is to be ched to the anatomical evidence by which they may be supported. he eye of the bird, the ciliary muscle, from its position and at- ments, must necessarily approximate the lens to the cornea; and reasons for considering the same part muscular in mammalia, and), for ascribing to it the same function as in birds, have been al- ly mentioned, and appear to us conclusive. We, therefore, on omical grounds alone, adopt this view, ably advocated by Por- eld,* conceiving that, when the eye is intent on near objects, the

* Treatise on the Eye. Vol. i. p. 446.

ciliary muscle is contracted, the lens advanced towards the cornea, and the latter membrane, perhaps, rendered more convex by the traction of the muscle on its border by means of the cordage of the posterior elastic lamina; while in vision of remote objects the lens is carried back towards the retina by the elasticity of the neighbouring parts. It is interesting to notice that this adjusting faculty of the eye is greatly impaired or altogether lost by extraction of the lens, or by paralyzing the ciliary and iridial muscles by belladonna. Dr. Clay Wallace considers that the ciliary muscle advances the lens by compressing the veins, and thus causing an erection or lengthening of the ciliary processes.

It has long been observed that the pupil is very prone to contract during near vision, and to dilate when the organ is adapted to view remote objects; and it has been imagined that this change is the necessary condition of adaptation, and may affect the lens through the ciliary body. In some persons, however, not at all deficient in the adjusting power, the iris continues to oscillate for some time after the eye is adjusted, without disturbing vision; and we have occasionally found the pupil to remain dilated, though a near object is being gazed at and the illumination remains the same. Moreover, the action of light on the pupil has no effect on the adjustment of the eye, since we can continue to see an object distinctly, whether it be viewed by a strong or by a feeble light.

These facts are sufficient to prove that the movements in the iris, usually coincident with the act of adjustment, are not the cause of that act. They seem rather to be of the nature of associate movements, produced by the close connection of the iris with the ciliary muscle, and by the community of source from which both these derive their motor nerves, viz., from the third pair, through the ophthalmic ganglion. And it is an important circumstance, that certain consensual movements of the eyeballs, performed through the medium of the third pair, are likewise associated with the act of adjustment. The movements of the iris chiefly minister to another function, the regulation of the quantity of admitted light.

The contraction of the pupil during near vision, by obstructing more of the circumferential rays, answers the important purpose of correcting the excessive aberration of sphericity which results from the greater divergence of the rays entering the eye from near objects.

Some persons have the power of adjusting the eye to distinct vision at different distances, either to a very limited extent or not at all; and we observe two states of vision connected with this defect, which are generally dependent on certain physical conditions of the lenses of the eye: these are shortsightedness, or myopia; and longsightedness, or presbyopia.

Myopia.—Thus, we meet with many persons who cannot distinctly see a yard before them,—who fail to recognize the features of their acquaintances in the street. In reading, they are obliged to bring the book close to their eyes: in looking at an object at all distant, they exhibit a characteristic winking (μυω, connivo). Myopia occurs in adolescence, and is accompanied with a too great refracting power

of the media, so that the image is formed anterior to the retina. In order, therefore, to throw back the image on the retina, the object is brought very close to the eye; or the convergence of the rays of light may be diminished by the use of a concave lens.

It seems probable that the state of myopia may be acquired by the habit of looking intently at small and near objects, and that the common practice of remedying the inconvenience by the use of concave glasses tends to increase the defect. Frequent exercise of the eyes on remote objects has, no doubt, the effect of making them far-sighted. It is a common error to say that myopia disappears naturally in advanced life.

Presbyopia.—Others again imperfectly distinguish near objects, whilst they see distant ones very plainly, and the distance at which they can see distinctly is sometimes very great. Persons thus affected cannot read small print with the eyes unassisted, and they prefer holding the book at a distance. This condition of vision is connected with a too flat cornea, a deficient aqueous humour, or a flattening of the lens: and it is in a great degree accounted for by the diminution in the refracting power thence resulting, so that the focus is behind the retina. It belongs to the advanced periods of life. It may be corrected by convex glasses, which increase the convergence of the rays of light.

It is manifest that neither of these defects is dependent on the muscular apparatus of adjustment, but rather on the curves of the refracting media, which throw the organ in one direction or the other beyond the range of the adjusting power with which it is provided. When the refracting media are optically corrected, as by the use of glasses, the adjusting faculty can be exercised.

In the eye, considered as an optical instrument, there are other powers besides those already named, which serve to make it more perfect, and to place it in favourable contrast with the most successful creations of human ingenuity.

One important office of the iris is to prevent the passage of rays through the circumferential part of the lens, and thus to obviate that indistinctness of vision which would arise from *spherical aberration*, or that unequal refraction which results from the difference in the angle of incidence of the several rays on a curved surface. In this respect it resembles the diaphragms used in optical instruments. By its position, close to the surface of the principal lens,—and behind or within the first one by which the light is converged, viz., the concavo-convex one formed by the cornea and aqueous humour,—it is adapted to admit the greatest quantity of light to the lens, consistently with the correction of the spherical aberration.

The aberration of sphericity is further obviated by the increased density of the lens from its surface towards its centre, so that the rays falling on its middle region are made more convergent as they traverse it, than those passing near its border.

Chromatic aberration, or that which occasions a coloured image by the inequality of the refraction of the elementary colours of white

light by the same medium, is in some way prevented in the human eye, when adjusted to distinct vision.

The image formed by a convex lens is slightly coloured at its margin. This colouring is corrected in practice by a compound arrangement of lenses differing in shape and density, of which the second, while it continues the convergence of the rays from their original course, re-associates the dispersed colours and recomposes the white light.

The achromatism of the eye may be in part due to the diversity of shape and density of the refractive media, which seem to bear some analogy to the system forming the achromatic object-glass of Herschel. This is formed of a double convex lens of crown-glass, with surfaces of unequal curvature, the more convex being turned towards the object; and of a concavo-convex of flint-glass, the concave side of which receives the lens of crown-glass, while its convex side is towards the eye. The cornea and aqueous humour form a concavo-convex lens which differs in density from the crystalline.

It is possible that the greater density of the inner fibres of the lens may likewise share in producing the effect. But this entire subject is involved in much obscurity, and it is right to add that some very high authorities, including Sir D. Brewster, deny that the chromatic aberration receives any correction in the eye; that, in fact, it exists in all cases, and is imperceptible only in consequence of its being so slight. It may be observed that when the eye is not adjusted to distinct vision, a coloured fringe is seen around objects. If the eye be fatigued and incapable of adjustment, or if belladonna be used, then colours are seen.

The rays of light which have now been traced to the retina, although they come to a focus in that membrane, yet can scarcely, from its extremely thin and transparent nature, be said to form an *image* upon it. The image, however, which becomes visible in the experiment on a dead eye, though partly due to the opacity the retina acquires soon after death, is yet an evidence that this membrane does not give passage to the light, like transparent glass, or the humours, but rather like ground glass, dispersing and reflecting some portion, as indeed its peculiar texture must dispose it to do. The pink colour of the pupil in albinos shows the reflection that occurs in those cases from the vascular choroid and retina; and Mr. Cumming has recently pointed out that in the eyes of all persons, where the pupil is tolerably large, a very decided reflection from the bottom of the eye may be observed under favourable circumstances. To make it apparent he places the individual at a distance of ten feet from a single gas-light or lamp, and directing him to look a little on one side, a strong glare becomes visible to any one standing almost directly between him and the light. In some persons this glare is exceedingly brilliant, like that from burnished brass; in others it is fainter. This reflection can hardly be regarded as important in a physiological point of view. It probably proceeds from the hyaloid membrane, the retina, and from the choroid also, but from the latter more or less according to the amount of pigment present in the particular instance. It is

narkable that these reflections do not interfere with the perfection the sense, do not derange the integrity of the impression resulting om the first passage of the rays. Corresponding but more vivid rections from the *tapetum lucidum* in certain animals serve a useful irpose, by giving an additional stimulus to the retina, where but a ible light is admitted to the organ.

Excitability of the retina, and of the allied nervous parts.—When e retina is stimulated, we have the sensation of light, whatever ay be the nature of the stimulus applied. Pressure, for instance, ade on the side of the eye in the dark, gives rise to the sensation a spot of light, the situation and size of which will be determined y those of the point of the retina touched. The same is true of the otic nerve, and of certain parts of the encephalon with which the erve is connected. The sensation of light, then, consists in a recognition by the mind of a certain condition or affection of these nervous arts, and this condition may be induced by the application of any of ie ordinary stimuli of nerves. The retina, however, is capable of eing affected in this way by the luminous rays; and perhaps this apacity is dependent on the peculiar manner in which the nervous atter is spread out in this part. However that may be, the light icident on the retina is the only stimulus which can naturally affect ; and the other parts, endowed with the same kind of excitability, n, in the natural state, be stimulated only in a secondary manner, though by induction through the retina. It is certain that the tegrity of these other parts is essential to vision, and it may therere be concluded that during vision they are all, immediately or ediately, in a state of excitation.

The retina is not affected sufficiently for the purposes of vision by very faint light; and, on the other hand, a very strong light, espeilly if long applied, will produce effects analogous to those resulting om an inordinate stimulus to other organs: the blood-vessels of the ina will become unduly injected, its nutrition disordered, and even texture destroyed. But the retina exhibits a considerable power accommodation to different amounts of light, and thereby the utility the organ is much enhanced, as well as its safety provided for. ter a short stay in the dark, objects disclose themselves, which at st were imperceptible; and, on the other hand, a light which was first too bright, becomes agreeable by use. This adaptability is ite independent of the iris, and has its analogue in the case of ery nerve of sense.

The *iris*, however, by its contractile power, is a most important ent in protecting the retina from the effects of sudden transitions om dark to light; and in thus co-operating for the maintenance of most essential quality, excitability, the iris is seconded by the eyels and brows. The iris contracts under a strong light, by virtue of e stimulus imparted to the retina; for if this or the optic nerve be stroyed or paralyzed, as in amaurosis, the iris no longer contracts. is interesting, however, to notice that the iris of the unsound eye ll often contract in company with its fellow, when the opposite und retina is stimulated. The motion is therefore evidently caused

by a reflexion of the stimulus from the optic nerve, through the nervous centre along the inferior branch of the third pair to the iris, and the consensual action of the two sides is effected in the nervous centre. Mechanical irritation of the ciliary nerves, or third pair, occasions contraction of the pupil on the same side. The orbicularis palpebrarum and corrugator supercilii likewise contract under a powerful glare, in obedience to a stimulus reflected through the optic nerve, and quite independently of the will. This is well exemplified in children affected with strumous ophthalmia, in whom the excitability of the retina is highly exalted.

The *pigmentum nigrum* is a permanent shield to the retina, absorbing the light which falls upon it, and remaining the same under all degrees of illumination. The excitability of the retina in creatures usually exposed to the full light of day, requires this additional protection; and where it is deficient, as in albinos, an ordinary light becomes painful, and the movable protecting parts are habitually brought into increased use. In animals of nocturnal habits, furnished with a tapetum lucidum, the excitability of the retina is probably somewhat modified, and the iris also is generally larger, and capable of an ampler range of motion.

Duration of impressions on the retina.—We continue to see an object after the rays of light emerging from it have ceased to fall upon the retina, and this for a period proportioned to the intensity and duration of the impression they have left. The familiar experiment of twirling a lighted stick, so as to see a luminous circle, shows that the impression made by it, when at any one point of space, remains on the retina until it reaches that point again. By ascertaining the speed necessary for completing a luminous circle of a certain size we can estimate the duration of the impression; and by augmenting or diminishing the brilliancy of the ignited point its duration is found to be affected. A momentary impression of moderate intensity continues for a fraction (according to D'Arcy, about an eighth part) of a second. But if the impression be made for a considerable time on any one point of the retina, it endures for a longer period after the object is removed. It is owing to this retentive power of the retina, that the rapid and involuntary act of winking does not interfere with continuous vision of surrounding objects.

Appearances of objects remaining after the removal of the objects themselves from the field of vision, come under the head of *ocular spectra*. In figure they correspond to the image the object has thrown on the retina, but they are of the complementary colour to that of the object. Thus, the spectrum left by a red spot is green; by a violet spot, yellow; by a blue spot, orange; and these colours of the spectra are particularly obvious when the eye is directed towards a white ground. It is further remarkable, that after long gazing on a very bright light, as the sun's disc, the remaining spectrum, if viewed on a white surface, assumes the different colours in succession, from black, through blue, green, and yellow, to white: if viewed on a black surface, the order of the succession is reversed. These several phenomena can only be referred to particular states or modes of exci-

ition of the retina, by means of which alone it is that the differences f the component colours of white light are made evident to our pereptive powers.

It appears by a simple experiment, for the principle of which we re indebted to Mariotte, that the small portion of the retina correponding to the entrance of the optic nerve, is incapable of exciting isual sensation though it receive the image of an object. Place the humbs together at arm's length, shut the left eye and fix the right ye steadily on the left thumb; then the right thumb, if moved gradully outwards (so that its image on the retina of course traverses nwards), ceases to be visible in a particular spot, but is again seen beyond it. It will be remembered that the fibrous lamina of the gray nervous layer of the retina is here evolving itself from the nerve, and s *not yet invested with the vesicular or other laminæ;* a circumstance of great interest in regard to the *modus operandi* of the constituents of the retina in vision.

It has indeed been denied by an eminent physiologist, that the etina is insensible to light at this point, on the ground that, if such were the case, we should see a dark spot in our field of view whenver we use only one eye. To produce the physical sensation of darkness, however, the retina seems as necessary as the nerves of rdinary feeling are to the production of the physical sensation of old. Both sensations are occasioned by the absence of the respective timulus, but the specially endowed nerve is as essential to acquaint s with the absence as with the presence of the stimulus. What Mariotte's experiment proves is simply that over that spot no nervous matter, having the peculiar power of excitability by light, exists; and s far as the faculty of seeing with that spot is concerned, it is as hough the piece of retina had been punched out. We no more see dark spot corresponding to it, when we look with one eye, than e see everything dark behind us—where there is no nervous expanon visually endowed. For, in strict language, a distinction must e drawn between the sensation of darkness and the absence of the ensation of light.

This incapacity of vision at the entrance of the optic nerve, seems be essential to the mode of junction of the retina with the nerve, nce it appears to have been the chief reason why the nerve was not made to enter in the axis of the eye. If the blind spot had been tuated in the axis, a blank space would have always existed in the entre of the field of vision, since the axes of the eyes, in vision, are made to correspond. But, as it is, the blind spots do not correspond hen the eyes are directed to the same object; and hence the blank, hich one eye would present, is filled up by the opposite one.

Though no other part of the retina is insusceptible of luminous npressions, yet there is good reason to suppose that the hinder part f it is much more capable of appreciating them than the anterior. When using one eye only, we naturally direct it towards the object e wish to inspect, and in that way throw the image to the bottom the globe. When the eye is thus fixed, objects near the boundary the field of vision are less distinctly seen than those at its centre.

The posterior part of the retina, too, is the best adapted to receive correct images through the dioptric media, and we find its gray nervous layer becoming thinner and thinner towards its anterior border.

It is probable that the most anterior part of the retina is never used in vision, since it can scarcely receive rays directly from the lens. Dr. Young, by fixing the eye in the most natural direction, viz., forwards and a little downwards, and by then moving before it a luminous object, in various directions until it passed beyond the range of vision, ascertained the range upwards to be 50°; downwards, 70°; inwards, 60°; and outwards, 90°: the extent in each direction being limited by the contiguous parts of the face. An object, therefore, occupying only an angle of 120°, both in the vertical and horizontal direction, and suitably placed, would about fill the field of vision of a single eye, when the organ was fixed as above described. Now, it may be proved that no part of the image of such an object would fall on the anterior part of the retina.

Perhaps it is only in, or very near, the axis of vision, that sight can be said to be *perfect*. The existence of the yellow spot of Sœmmerring at that point continues a riddle which the most attentive examination of its anatomy has not yet solved. And from the absence of this spot in almost all the lower animals, we are led to doubt its importance to perfect vision.

To the perfect exercise of vision, as of all the other senses, an effort of *attention* is necessary; and this effort is naturally accompanied with a motion of the eyeball towards the object, so that the image may be thrown upon the central part of the retina. The range of motion of the eyeball Dr. Young calculated at 55° in every direction; so that, the head being fixed, a single eye may have perfect vision of any point within a range of 110°. This field is further widened by the use of the opposite organ, but beyond this an increased range is only to be acquired by movements of the entire head.

The internal, or gray nervous layer of the retina seems to be the essential part on which the power of the retina in the process of vision depends. That layer is an *unbroken sheet*, continuous by its fibrous internal surface with the axes of the tubules of the optic nerve, and having its external surface formed by a structure similar to that of the cineritious substance of the cerebral hemispheres. Its permeation by a close network of capillaries assimilates it still further to the gray nervous matter; for which reasons it may be considered as a portion of the cerebrum advanced towards the surface of the body into a suitable relation to a dioptric apparatus for the reception of rays of light from external objects. The optic nerve may be regarded as a commissure between the gray nervous sheet within the sclerotic, and the gray nervous matter of certain parts of the cerebrum. We have no more reason to deny the immediate connection of the sensorium with the retina, than its immediate connection with any small portion of the cerebral convolutions, duly united with the rest. The nature of the connections between the retina and the brain, and the phenomena to which their disruption gives rise, have been the occasion of many interesting speculations regarding the mode in which the

ind is reached, or, in other words, as to how an impression on the tina becomes a sensation to the mind. But we shall probably be isappointed if we imagine that any facts which have been or may e hereafter ascertained, are capable of leading to the solution of a roblem too inscrutable for our limited powers.

It is a matter of considerable interest, as regards the mode of action f the retina in vision, to determine how distant the images of two oints on the retina must be, to be seen distinctly as two; in other 'ords, how small a portion of the retina is capable of independent ensation. As the result of many experiments and calculations by mith, Harris, and others, this may be stated as probably about $\frac{1}{5000}$ f an inch, so that the objects must subtend an angle of at least 40". 'wo points within an angle of that size would appear as one. It is question somewhat different, what is the smallest portion of the etina capable of sensation; and undoubtedly an object whose sides ubtend an angle very much smaller than the preceding may be isible, if sufficiently bright. But this circumstance of quantity of ght introduces a difficulty into the inquiry, since even a mathematial point, if sufficiently brilliant and out of focus, might become isible by its circle of aberration on the retina; although, if its rays et in the retina, it would be invisible. But, in carrying our speculations thus far, we must cease to regard the retina as a mathematical lane, and remember that it has a certain thickness, in traversing which the rays would necessarily cover more than a point, either in ont of or behind the exact focus. It is obvious that a linear object ould be more perceptible than a point, and a moving object more than a stationary one, in consequence of wider and more distant ortions of the retina being affected in both cases.

The apparent truthfulness of a view, recently put forward on high ithority in Germany, and copied into several works in this country, akes it necessary to explain here that the rod-like particles of Jacob's embrane, though corresponding nearly in size with the points of the tina capable of independent sensation, yet being on the choroidal irface, and separated from the gray nervous layer by the intervening anules, can scarcely have a share in determining the size of the dependent visual points. The unfortunate error which placed these ds as papillæ on the hyaloid surface of the retina, was too tempting ground of theory not to be readily admitted as true, without scruilous examination; and the price to be paid will probably be some gree of discredit thrown on minute anatomical research.

Correct Vision with an inverted Image.—Visual idea of Direction.—he image on the retina being the reverse of the picture of external ijects seen by the mind, it is manifest that in some way or other the version is counteracted ere the impression becomes a sensation. It conceivable that this correction may take place in the optic nerve brain, but it is far more probable that it occurs in the retina. It certain that we do not see the image as it exists on the retina, or inversion would not have remained so long unknown; we rather e *out of* or *from* the retina. The simple experiment of pressing ith the finger on the retina through the ocular tunics, and thus

eliciting a luminous appearance on the opposite side, seems to prove that the apparent projection of a luminosity in a direction perpendicular to the point stimulated, is a necessary part of the excitability of the retina. If this be granted as an ultimate fact, it will explain why an inverted image, formed on a concave retina, shows objects in the same position as they are shown by the other senses which receive direct impressions from them, particularly touch.

It has been supposed by Müller and Volkmann, that objects do really appear inverted; but they argue that, as long as all do so, even visible parts of our own bodies, there is no need of a correction. But this will not explain the perfect harmony existing between impressions conveyed through the senses of hearing and touch, with those derived from sight. Sounds are appreciated, and tactile impressions are felt, as proceeding from a particular direction as regards the body—our several organs are conceived as existing in a particular relative position, altogether independently of vision—and vision accords entirely, and at once, with these senses in the determination of locality, without the necessity of an education of the sense, such as a reversed impression on the mind through the eye would require.

Were the eye and the whole body fixed, we should still have a knowledge of the relative position of visible objects, and of course of the direction in which each point of their surface was placed, as regards the organ of sense; and as rays coming from objects in the same direction as regards the body, would then always fall on the same part of the retina, we might conclude that each part of that membrane had the power of conveying the notion of position in one direction only as regards the body. But the eye being a very movable organ, we are enabled to make the image of a stationary object travel successively over a large tract of the retina without the object appearing to move; since we are conscious, through the muscular sense, of the motion in our own eye. The visual idea of direction in regard to the body, therefore, does not depend on the image falling on a particular point of the retina, but in a great measure on the muscular sense, in conjunction with that quality of the excitability of the retina already spoken of.

It is proper also to mention that the limits of the field of vision, formed by certain parts of the face, are a standard to which the mind refers in estimating the position of visible objects. The outline of the field remains the same, through all movements of the eye. The motions of the head or body can alone bring new objects into the field; and the muscular sense thus still further contributes to enhance the usefulness of the sense of vision.

Visual Perception of Shape and Size.—If an object form a large image on the retina, and of a square figure, we conceive it at once to be large and square; and of this no other explanation can be given than that the visual points making up the surface of the retina have, as regards space, a relation to one another, of which the mind is intuitively cognizant in framing its ideas from visual impressions. But the size of an image, relatively to the whole retina, will vary with the distance of the object; and the conception of its real dimensions

ld be erroneous, were it not that the impression were corrected he muscular sense engaged in the adjustment of the eye to dise, and by the lessons of experience. When a person, blind by ract from infancy, is couched, he concludes that the diversified ils of the scene presented to him are at an uniform distance, as picture; and a species of education can alone undeceive him. learns, through touch, that all objects are not equally near to him, gradually familiarizes himself with the changes in their apparent , distinctness and colours, produced by the movements of his le body with regard to them. The adjusting faculty is an addiil source of correct knowledge.

isual Perception of Motion in Objects.—When an object moves direct line, to or from the eye, its motion is inferred chiefly by change effected in the size of its image on the retina, as when a motive engine, at full speed, approaches the observer. When object moves in an arc, of which the eye is the centre, its mois known, if the eye be fixed, simply by the movement of its ge across the retina. But most motions occurring around us are wn in both these ways. When, too, the attention is excited to moving object, the eye is naturally moved in concert with it, rder to keep its image near the axis of the organ where vision ost perfect. Our appreciation of the direction and velocity of motion is thus heightened by the exercise of the muscular sense.

oubleness of the Organ of Vision.—The preceding account has ı almost confined to the phenomena of vision with a single eye; mains to be explained how the doubleness of the organ affects the e.

ı some animals the eyes are so placed as to look in different diions, and in these the images formed are, doubtless, independy recognized by the animal, just as are those thrown on different s of the retina of a single eye in ourselves. But where the eyes both directed the same way, it is manifest that a double image of ı object must be received, and that the singleness of the resultsensation must depend either on our noticing only one of these ges, or else on our forming a single conception from both conjoint- It is easy to prove that the latter is generally the case, although sometimes derive our information from the aff[illegible] of only one

he eyes are moved in concert by the muscles attached to them, hat their axes always converge towards the object to which they adjusted. The consequence of this is, that the corresponding its of the two images are made to occupy corresponding points of two retinæ, or very nearly so, and single vision is produced. If two images are unsymmetrically placed on the retinæ, as where optic axes do not converge to the object, a double sensation is ted. Thus, in squinting, two impressions are excited, unless, by habit, one eye ceases to be adjusted and employed, and gradually s its excitability: but when two similar objects are presented to eyes of a squinting person, one carefully in the axis of each, their ges coincide and they are seen as one. The double vision of

drunkenness, and of certain cerebral affections, is explicable partly on the same ground, but in such cases considerable allowance must be made for the disordered state of the sensorium. Again, if corresponding points of the two retinæ are pressed by the finger, a single luminosity is perceived; but a double one, if the points touched are non-symmetrical. Something similar to this blending of two impressions in one sensation exists in the sense of hearing, and, perhaps, also in taste and smell.

The corresponding points of the two retinæ are such as would be in contact, if the two retinæ were adapted to one another: the upper and lower parts correspond with the upper and lower, and the inner side of one with the outer side of the other.

As we are entirely ignorant of the mode in which the mind takes cognizance of a single impression on an organ of sense, we cannot hope to understand how a single sensation can result from a double impression. But it is most interesting to remark a structural peculiarity in the course of the optic nerves, which certainly allies itself with this wonderful part of their function. Their partial decussation in the chiasma, or commissure, connects each retina with both optic tracts, and with the corresponding portions of the cerebrum; and it is not improbable, as Dr. Wollaston conceived, and Mr. Mayo has described, that the right side of both retinæ is continuous with the right optic tract, and the left side of both with the left. This would place each side of the central apparatus in connection with its own side of both the symmetrical images, and might be supposed to favor their conception as one. Dr. Wollaston relates, that on different occasions he lost the power of seeing one half of an object to which he directed both eyes; and others have experienced similar temporary attacks. Thus, Abernethy would humorously affirm that he could sometimes see only his *ne* and *thy*, having lost the other members of his name. Such phenomena are readily explained by supposing the anatomical arrangement of the sides of the retinæ, with regard to the optic tracts, to be such as above described, since any derangement of one optic tract would then affect the same part of both optic images. Indeed, in Dr. Wollaston's own case, a tumour was found involving one of the optic tracts, as had himself inferred from the phenomenon above mentioned.

What we have before advanced, however, regarding the unbroken sheet of gray nervous matter in the retina, leads us to attach even more importance to the commissural fibres which appear to connect the two retinæ together, through the medium of the chiasma, and independently of parts behind it. We conceive that these commissural fibres may connect corresponding parts of the retina, much in the same way as corresponding parts of the cerebral convolutions of the opposite hemispheres are linked together by the corpus callosum or other commissures; and that the unity of action of the double organ may depend, as to its physical cause, on the same principle in both.

This capacity of forming a single conception from a double impression may appear, at first sight, to be given simply to obviate con-

usion; but Mr. Wheatstone has most ingeniously shown that it confers a new power on the sense, viz., that of appreciating forms projected in relief.

Such objects, if sufficiently near the eyes for the optic axes to converge in viewing them, are seen from two different directions: they are represented on each retina by a different perspective projection; and the more so, the nearer the object to the observer.

Mr. Wheatstone has shown that the single sensation excited by these two images is that of a third image different from them both, but excitable only by both of them at once, and attended with the notion of solidity, or projection in relief. He has illustrated this by an instrument which he terms the *stereoscope*. Some object of three dimensions (as a cube) is represented in two drawings as it would be seen at a small distance by each of the two eyes. These drawings are then placed symmetrically in the right and left compartments of a small box, so as to be reflected by sloping mirrors to the eyes of the observer, each view to its corresponding eye. When he looks at each separately, it seems a mere drawing on a flat surface; but when he regards both views at once, they appear to coalesce, and a solid prominent figure seems to occupy their place. Mr. Wheatstone has also shown that the same effect occurs, although there may exist some disparity between the size of the two images; and that the resultant idea is that of a figure of intermediate size. Now, unless an object is placed directly in front of the eyes, its image is larger in one eye than the other, because it is nearer one eye than the other; and this faculty of striking a mean between the two impressions is, therefore, constantly made use of.

The above facts abundantly prove the non-existence of *absolutely corresponding* points on the two retinæ, such as were formerly held to exist. But they do not invalidate what has before been advanced respecting the general correspondence of certain tracts of the two retinæ, and the absolute non-correspondence of others.

Mr. Wheatstone further observes, that if two dissimilar images are represented at once to the corresponding parts of the two retinæ, they are not blended, but seen alternately, according to their distinctness and degree of illumination. This is a very singular circumstance, and agrees closely with what takes place when dissimilar colours are viewed in the same way.

On the subjects treated of in this chapter, reference is made to the following works: Zinn, Descriptio Anatomica Oculi Humani; Haller, Elementa Physiologiæ, tom. v.; Porterfield on the Eye and Vision (an admirable work); Dr. Jacob's paper on the Phil. Trans. 1819, and in the 12th vol. Med. Chir. Trans., and the article "Eye" in the Cyclop. Anat. and Phys., by the same author; Mr. Dalrymple's Anatomy of the Eye, London, 1834; the introduction to Mr. Lawrence's Treatise on Diseases of the Eye, 2d Edit., 1841; Mr. Wharton Jones' Essay prefixed to MacKenzie on Diseases of the Eye; Arnold, über das Auge des Menschen; Sœmmerring's Plates of the Eye; Müller's and Wagner's Physiology; Mackenzie on Vision; Bowman (W.) Illustrations of the Anatomy of the Eye in health and disease, now in course of publication.

CHAPTER XVIII.

OF HEARING.—THE ORGAN OF HEARING.—ITS DEVELOPMENT IN THE ANIMAL SERIES.—THE EXTERNAL EAR.—THE TYMPANUM.—THE LABYRINTH.—THE FUNCTIONS OF THESE PARTS.

It is by the sense of hearing that the mind takes cognizance of those oscillations of elastic matter which give rise to the phenomena of sound.

The communication of these oscillations to the ear may take place through the air, or through the intervention of some solid conductor, brought into immediate connection with the organ of hearing.

The essential part of the organ of hearing is a sac, containing fluid, upon which the nerve of hearing is freely distributed: this sac being in connection with the cranial parietes. This is represented in the human subject by that small cavity which is excavated in the petrous portion of the temporal bone, called the *vestibule*. This, and *three semi-circular canals*, with a spirally disposed canal, divided by a partition, constituting the *cochlea*, form *the labyrinth*. External to this, and situate between the squamous and petrous portions of the temporal bones is a cavity, *the tympanum*, which in front further communicates very freely with the cavity of the throat through an open channel, *the Eustachian tube*, whereby air has a free access into the tympanum. This cavity is closed on the outside by a membrane (*membrana tympani*) which extends over its external orifice as over a drum. A communication is established between the membrane and the inner wall of the tympanum, by a chain of small bones which extends from the one to the other. These are the *ossicles* of the ear. The outer bone of the chain is intimately attached to the membrana tympani, and the inner one to a membrane which closes the vestibule on the outside. The three bones which compose the chain are articulated by moveable joints, and are moved by small muscles, which are thus enabled to regulate the tension of the membrana tympani, as well as of the membrane of the vestibule. Externally is an apparatus for collecting sounds, and conducting them to the tympanum.

Development of the Organ of Hearing in the Animal Series.—There is no organ in the body in which we find a more remarkable gradation of development in the various classes of animals, than in the ear. We see it existing as a simple sac in the cephalopod and gasteropod mollusks, and in crustacea. In the cuttle-fish, it consists of a small sac filled with fluid, lodged in a chamber excavated in the cranial cartilage. The chamber is closed everywhere except at the entrance of the auditory nerve, which passes in to expand upon the sac. From its inner surface there project several obtuse processes, of a soft, elastic nature, which support the sac. The sac contains a calcareous body or *otolithe*. Even at this early stage of development the organ is double, and the two cavities are separated from each other by a very thin septum. It is obvious that these cavities are strictly analogous to the vestibule in the higher classes.

In Gasteropoda, the organ consists of a sac, to which the nerve is distributed, and

ich contains fluid and several small otolithes, which, according to Siebold, exhibit narkable movements.

n Crustacea, the organ still exists as a simple sac. This, as Dr. Arthur Farre has ›wn, is situate, in the lobster, in the base or first joint of the lesser antenna. Its ce is indicated by a tough membrane which covers an oval aperture in the upper face of this joint; the membrane being a continuation of the same structure which ms the shell, but in which the earthy matter is wanting. Towards the inner and terior margin of this membrane, there is a small round aperture, through which a stle may be passed. "On removing this oval membrane, together with a portion the surrounding shell, the internal organ is brought into view, completely imbedded the soft integument and muscular structure of the antenna." It consists of a sac, shape like an auricle, and of a horny structure, like soft quill, suspended in the ntre of the joint, free on all sides, and having only a single attachment near the erture in the oval membrane already described; it nearly fills the cavity of the int. The sac contains particles of siliceous sand, which find their way into it rough the aperture already described, and probably fulfil the office of the otolithes hich exist in other classes of animals. Numerous very remarkable ciliated prosses are attached to the lower surface of the vestibular sac: they are arranged in a micircular line. In the neighbourhood of this line the auditory nerve attaches elf to the sac, and forms a plexus, which covers the whole under surface of the c, extending also towards its upper surface. The nerve is derived from the lesser d greater antennal nerves.

Dr. A. Farre has shown that the cavity situate at the base of the greater antenna not, as has been hitherto supposed, suited to act as an organ of hearing. It is a nical papilla, abruptly truncated, and having stretched over it a membrane, which pierced in its centre by an aperture capable of admitting a small bristle. On king a section of this part, nothing more is seen than a narrow canal in the thy substance leading perpendicularly from the external orifices, and terminating ruptly at the depth of two lines. A nerve is sent off to this organ from the supraophageal ganglion. Such an organ is very ill-adapted for hearing. Dr. Farre s ascertained that this is the most sensitive part of the body of the lobster; nce, while the mechanical irritation of any other parts excited only a slight vement in the limbs of the animal, when out of water, and somewhat feeble, the ching of this part was immediately followed by a violent and almost spasmodic ping of the tail." (*Farre on the Organ of Hearing in Crustacea.* Phil. Tr. for 3, p. 233.)

n Fishes the organ of hearing acquires a considerable increase in the complexity ts organization. It consists of a vestibular sac, with the accession of, in general, e semicircular canals. In the myxine, however, a fish of very low organization, re is only one of these canals. In the lamprey there are only two. The vestibular consists of a large sac (*utriculus* of Breschet), into which the semicircular canals n, and with the walls of which they are continuous, and of a small offset from larger one (the *sacculus* of Breschet). This apparatus is composed of a thin, nsparent, elastic membrane. It is filled with fluid, and contains in each sac, either celainous bodies (*otolithes*), of beautiful structure and great diversity, as in the eous fishes, or masses of pulverulent deposit, like powdered chalk (*otokonia*), as he cartilaginous fishes. These, whether hard or soft, consist of carbonate of lime, therefore may be quickly decomposed by a mineral acid. The whole of this itory apparatus is deposited in an excavation of the cranial wall, which commuates with the cavity of the cranium itself, excepting in the rays and sharks, in which enclosed by the cranial cartilages. It is suspended in fluid (part, probably, of cerebro-spinal fluid), which constitutes the analogue of the perilymph in the her animals. In some fishes, according to Breschet, an additional offset from the ger sac exists, to which he gives the name *cysticule*. All these parts are analogous he membranous labyrinth of the higher animals, there being nothing to represent tympanum or the cochlea. In many of the osseous fishes the auditory apparatus no communication whatever with the exterior. In rays and sharks, however, a longation of the labyrinth extends through an opening in the occipital portion of skull to the surface just beneath the skin. In many fishes, according to Weber, re is an intimate connection between the auditory apparatus and the swimming lder, although their cavities have no communication with each other.

n Amphibia, the auditory apparatus is closed off from the cranial cavity, and is tained in the cranial bones. It consists of a vestibule with three semicircular als. In some, there is placed external to this labyrinth a tympanic cavity,

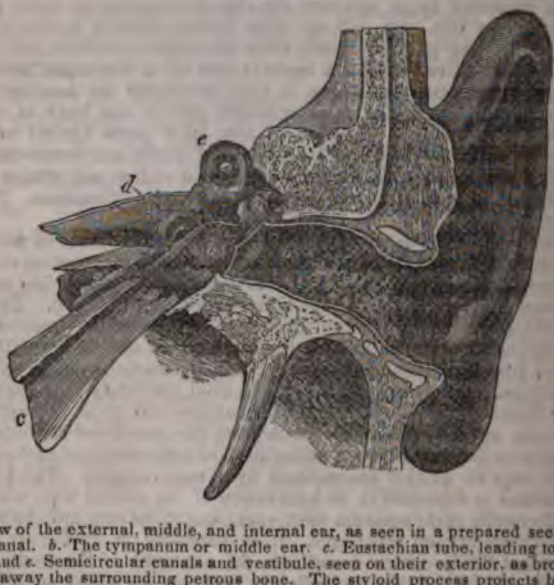
closed on the exterior by a membrane, which is intimately united with, or a portion of, the integument, or a thin layer of cartilage. An osseous pillar (the columella), or a chain of two or three ossicles, extends from the wall of the vestibule to this tympanic membrane, analogous to the tympanic bones in the human subject. In the Reptiles, there is a short canal connected with the vestibule, analogous to the cochlea. The existence of this canal establishes that of a second external opening belonging to the labyrinth, or *fenestra cochleæ*, in addition to the *fenestra vestibuli*. Some of the Reptiles, as the serpents, are devoid of a distinct tympanic cavity; but the existence of a columella beneath the skin indicates a rudimentary state of it. In others, as the tortoises, crocodiles, and lizards, such a cavity exists, with its usual canal of communication with the fauces, the Eustachian tube, and with a columella. The fluid of the labyrinth contains crystalline particles in place of otolithes.

In Birds, the organ of hearing has the same parts as in the higher reptiles. Its labyrinth has the cochlea and semicircular canals, and the two fenestræ, and there is a tympanic cavity with a columella. The cochlea is a very slightly bent canal, divided by a membranous septum into two passages, scala vestibuli, and scala tympani.

In Mammalia, the general characters and structure of the organ of hearing closely resemble those of man.

In examining the anatomy of the human ear, we shall first describe the external ear, next, the middle ear, or tympanum, and lastly, the labyrinth.

Fig. 131.



General view of the external, middle, and internal ear, as seen in a prepared section through *a*, the auditory canal. *b*. The tympanum or middle ear. *c*. Eustachian tube, leading to the pharynx. *d*. Cochlea; and *e*. Semicircular canals and vestibule, seen on their exterior, as brought into view by dissecting away the surrounding petrous bone. The styloid process projects below; and the inner surface of the carotid canal is seen above the Eustachian tube. From Scarpa.

The *External Ear* comprises the free, expanded part, *auricle* or *pinna*, and the *auditory canal* or *external meatus*.

The *auricle* presents an outer surface, which is on the whole concave, and slightly inclined forwards. On this surface are several eminences and depressions, resulting from the folded, or rather crumpled, form of its cartilaginous basis, and which are seen reversed on the free portion of the opposite surface. These are:—a prominent rim or *helix*, and within it another curved prominence, the *anthelix*,

which bifurcates above, so as to enclose a space, the *scaphoid fossa*, and describes a circuit round a deep, capacious, central cup, the *concha*. At the end of the helix, in front of the concha, is a small detached eminence, the *tragus*, so named from its bearing a tuft of hair resembling a goat's beard. Opposite this, behind and below the concha, is the *antitragus*. Below is the pendulous *lobe*, composed of dense areolar and adipose tissues. The *concha* is imperfectly divided into an upper and a lower part by the anterior curved extremity of the helix. The *groove of the helix* is continued into the upper division, and the auditory canal leads from the front and deepest part of the lower division where it is overhung by the tragus and its protective tuft of hairs. The cartilage of the pinna consists of one principal piece, from which that of the tragus and antitragus is separated by a fissure filled up by fibrous membrane. It is very flexible, and elastic, has a yellowish colour, and belongs to the same category as the cartilages of the alæ nasi, &c. Ligamentous fibres bind the concha behind and above, and the tragus in front to the bone and fascia in the neighbourhood. A few muscular fibres passing between different parts of the auricle, serve to impress upon them movements, but so slight as to be hardly worthy of note. These fibres are found externally on the tragus, the antitragus, the upper end of the helix, and behind on the concha. The whole of the cartilaginous part of the ear is rendered movable by three muscles, the *superior* and *anterior auris*, arising from the epicranial aponeurosis, and converging to the concha and helix, and the *posterior auris*, passing between the mastoid process and concha.

The *auditory canal* passes from the concha inwards for about an inch, or rather more. It inclines a little forwards, and is slightly bowed, so as to be higher near the middle than at either end. Its width does not equal its height, and it is altogether narrower in the middle. The membrana tympani, which terminates it, is placed obliquely, in consequence of the lower side of the meatus being longer than the upper. The canal consists of two parts, a cartilaginous and fibrous one, and an osseous. To form the first, the cartilage of the concha and tragus is prolonged inwards as far as the auditory process of the temporal bone, and constitutes a tube imperfect at the upper and back part, where its deficiency is supplied by fibrous membrane. This cartilage is rendered still further movable by partial slits in a vertical direction (*incisuræ Santorini*). Muscular fibres are described by some to exist in the meatus, which, according to Haller, become shortened by their contraction. The osseous part of the auditory canal consists in the fœtus of a ring of bone, to which the membrana tympani is attached (*tympanic ring* of the temporal bone). In the adult, it is nearly three-quarters of an inch long, and gives the meatus the form and direction already described.

The skin of the external ear is delicate, and well supplied with vessels and nerves. The orifice of the meatus, besides being concealed behind the tragus, is defended by hairs, and a close arrangement of ceruminous glands, which furnish an abundant secretion, calculated to entangle particles of dust, or small insects, and to pre-

vent their entrance into the organ. These glands are principally seated in the subcutaneous tissue, where the cartilage is deficient, and do not extend into the osseous portion of the canal. The *cerumen* is an oily, very bitter substance, of a yellow colour, and contains, in addition to fat, albumen, and colouring matter, a bitter principle analogous to that of the bile. If not removed from time to time, it is liable to form hard pellets, which either impact the passage, or come into contact with the membrana tympani, and in either case seriously interfere with the transmission of sound to the internal parts. These concretions are partially soluble in ether and turpentine.

The *Middle Ear*, or *tympanic cavity*, is a space filled with air, communicating with the pharynx by the Eustachian tube, and interposed between the external meatus and the labyrinth. It opens behind into the mastoid cells, which are also filled with air, and it is traversed by a chain of moveable bones, connecting the membrana tympani with the vestibule, or common central cavity of the labyrinth. The tympanum is of irregular shape, compressed laterally, and lined by a very delicate ciliated epithelium, prolonged from the pharynx.

The external wall of the tympanum is formed by the *membrana tympani*, and a small extent of the surrounding bone. The membrane is nearly oval, but wider above than below, and as already stated, placed in a slanting direction, so as to form an obtuse angle with the upper wall, and an acute one of about 45° with the floor of the auditory canal. It consists of three laminæ, an external, middle, and internal. The external is derived from the cuticular lining of the canal, and easily detaches itself with that structure after maceration. The middle is strong and fibrous, perhaps analogous to the dermal part of the integument, and attached through the medium of a dense fibrous rim to the bone, which presents a distinct groove for its reception, except above. The handle of the malleus is firmly united to this layer of the membrane, in a vertical direction as far down as the centre, and draws the membrane inwards along that line, so that its outer surface is concave, its inner convex. The abundant small vessels supplying this part run along the handle of the malleus, and thence radiate more or less directly towards the border. The fibrous tissue is in part similarly disposed, and thus seems to have led Sir E. Home to describe a radiating muscle in the membrane, which does not appear to exist. Seen from within, a concentric arrangement of the fibres is more obvious. The inner layer is the ciliated epithelial lining of the cavity, which is easily scraped off for examination in the fresh state (see p. 73).

The *internal wall* of the tympanum (fig. 132) has two orifices of communication with the internal ear; the *fenestra ovalis*, *a*, leading to the vestibule, and the *fenestra rotunda*, *b*, opening into the cochlea. Both these are closed by membrane which prevents the escape of the fluid contained in these inner chambers, and communicates vibrations to it. The fenestra ovalis is likewise occupied by the base of the stapes, one of the chain of ossicles connecting it with the membrana

ympani. Between the fenestræ is the *promontory*, *c*, corresponding the first turn of the cochlea, and furrowed by two or three canals r the nerves which form the *anastomosis of Jacobson*, *n*. Behind e fenestra ovalis is a conical eminence, the *pyramid*, *d*, hollowed, nd presenting a small orifice at its summit, which is on a level with e middle of the vestibular fenestra. The pyramid contains the tapedius muscle, the tendon of which emerges at its summit, and

Fig. 132.

Diagram of the inner wall of the tympanum after maceration, the outer wall and ossicles being moved. *a*. Fenestra ovalis. *b*. Fenestra rotunda. *c*. Promontory. *d*. Pryramid, with the orifice its apex. *e*. Projection of the aqueductus Fallopii. *f*. Some of the mastoid cells communicating ith the tympanum. *g*. Processus cochleariformis, bounding *i*, the canal for the tensor tympani uscle: the anterior pyramid is broken off, if it existed. *h*. Commencement of the Eustachian tube. Jugular-fossa, immediately below the tympanum. *k*, *k*. Carotid canal, with the artery in outline, show its course in relation to the tympanum and Eustachian tube. *l*. Portio dura of the seventh ir of nerves, as it would be seen in the terminal part of the aqueduct of Fallopius. *m*. Chorda mpani, leaving the portio dura, and entering a short canal, which opens in the tympanum, at the se of the pyramid. *n*. Grooves for the tympanic plexus.

uns to the neck of the stapes. This muscle is supplied by a twig om the portio dura of the seventh pair. At the base of the pyramid an aperture through which the chorda tympani, *m*, enters the ympanum. Thence this nerve passes forwards, between the handle f the malleus and the long arm of the incus, and emerges through a anal close to the Glaserian fissure. Above the pyramid an arched rominence, *e*, indicates the course of the aqueductus Fallopii, close the tympanum; and behind this is the free communication with e mastoid cells, *f*.

The anterior part of the tympanum presents above the canal for e tensor tympani muscle, and below the orifice of the Eustachian ibe. The former, *i*, is chiefly formed by a curled plate of bone, the *rocessus cochleariformis*, *g*, ending in a kind of perforated summit, at some have termed, *anterior pyramid*. This is a little above the nestra ovalis, and gives passage to the tendon of the tensor tympani, which becomes attached to the short process of the malleus.

The *Eustachian tube*, about one inch and a half in length, leads from the tympanum downwards, forwards, and inwards, to its orifice in the pharynx, which is seen as a slit with an elevated edge close behind the inferior turbinated bone of the nose (see fig. 106, *t*, p. 396). By its straight, but inclined course, the passage of mucus from the tympanum is facilitated. Its upper extremity for more than half an inch is bony, while in the rest of its extent it is cartilaginous. It dilates at each end, especially the lower, where the cartilage is thickened and everted. It forms a passage for the air in and out of the tympanum. It exists in all animals in which a tympanum is found, but in many, the tubes of opposite sides have a common outlet on the pharynx. External to the opening for the Eustachian tube is the opening for the anterior muscle of the malleus (Glaserian fissure) and that for the escape of the chorda tympani.

The *ossicles of the tympanum* are three, the malleus, the incus, and the stapes (fig. 133). The *malleus* (hammer) has a large extremity above, termed the head, *m*, bounded by a constriction or *neck*, from which the *handle* (manubrium), *h*, passes down, imbedded in the membrana tympani, as already described. Its concavity directed outwards explains the similar inequality of that membrane. The *short process* is a slight conical projection from the neck, which receives the insertion of the tensor tympani muscle: the *slender process* (p. gracilis), *g*, also passes from the neck, but forwards and outwards, to enter the Glaserian fissure. On the back of the head and neck an articulation is formed with the incus. The *incus* (anvil), is shaped not unlike a molar tooth. It articulates with the malleus by the anterior surface or summit of its *body*, and has two processes, a *short* and a *long crus:* the former, *sc*, has a backward direction, and projects into the mastoid cells, the latter, *lc*, descends to a level with the fenestra ovalis, bends inwards, and is tipped with a *lenticular process*, to which the head of the stapes is attached, *a*. The *stapes*, or stirrup bone, *s*, is almost sufficiently described by its name. Its construction is truly elegant. It has a *head*, *neck*, *two branches*, and a *base*. The last fits into the fenestra ovalis, to the margin of which it is attached, by membrane, so as to enjoy some freedom of motion. Its neck receives the insertion of the stapedius muscle. The chain of ossicles, now described, stretches across the tympanum by no means in a straight line, and its parts are permitted to enjoy some degree of motion, not merely by the double joint existing between them, but by the mode of their attachment at either end.

Fig. 133.

Ossicles of the left ear articulated, and seen from the outside and below. *m*. Head of the malleus, below which is the constriction, or neck. *g*. Processus gracilis, or long process, at the root of which is the short process. *h*. Manubrium, or handle. *sc*. Short crus; and *lc*, long crus of the incus. The body of this bone is seen articulating with the malleus, and its long crus, through the medium of the orbicular process, here partly concealed, *a*, with the stapes. *s*. Base of the stapes. Magnified three diameters. From Arnold.

These bones are moved by small muscles, two of which are not

ωnted. These are the *internal muscle of the malleus*, and the *sta-ius* muscle. Each of these muscles consists of striped fibres.

The *internal muscle of the malleus*, or *tensor tympani*, occupies the al above the osseous portion of the Eustachian tube. It is at-hed in front to the under surface of the petrous bone, and to the tilage of the Eustachian tube; it proceeds backwards, and ends a tendon which turns abruptly outwards from the osseous canal in ich the muscle is lodged, and is inserted into the short process of malleus. It draws this part inwards, and thus heightens the ten-n of the membrana tympani. An *anterior muscle of the malleus*, *laxator tympani* muscle, is described by many anatomists as passing m the Glaserian fissure to the processus gracilis. The *stapedius uscle* occupies the conical interior of the pyramid; its surface is oneurotic, its interior fleshy, and it terminates in a small tendon iich emerges at the apex of the pyramid, and then passes to be erted into the neck of the stapes. In contraction it would fix the pes by pulling its neck backwards. It probably compresses the ntents of the vestibule.

Of the Internal Ear, or *Labyrinth*. This is the potential part of organ of hearing, and includes the ultimate distribution of the rve. It consists of three parts, the vestibule, the semicircular als, and the cochlea, all of which, from their delicacy and minute-s of structure, demand careful examination. They are a series of ities hidden in the hardest part of the petrous bone, communicating the outside with the tympanum, by the fenestræ ovalis and rotunda ady described, and on the inside with the internal auditory canal, ich conveys the nerve to them. The very compact bone imme-tely bounding these cavities, considered apart from the less dense e which surrounds it, is termed the *osseous labyrinth*, in distinction n a *membranous labyrinth* within.

Of the Osseous Labyrinth.—The singularly complex shape of this t of the organ makes it difficult to describe. 1. The *vestibule*, or mon central cavity, placed immediately to the inner side of the panum, is flattened from side to side, and about a fifth of an inch eight, as well as from before backwards. The semicircular canals n into it by five orifices behind, the cochlea by a single one in t; on its outer wall is the fenestra ovalis, on its inner several ute holes, including the macula cribrosa for the entrance of a por-n of the auditory nerve from the internal auditory meatus. At the der part of the inner wall is the orifice of the aqueductus vestibuli, e canal penetrating the vestibule from the posterior surface of the rous bone, and containing, as some describe, a tubular prolongation the lining membrane of the vestibule, ending in a minute pouch ween two layers of the dura mater, within the cranial cavity. chet considers this to be an evidence of a continuity once exist-between the lining membrane of the cranium, and that of the tibule, and it is certain that in most fishes the vestibule is a pro-s of the cranial cavity, or separated from it only by a membrani-n septum. Whatever other use the aqueduct of the vestibule may

serve, it seems, certainly, to convey small vessels to the internal ear. The lower part of the inner wall presents a hemispherical depression (*fovea hemispherica*), and immediately above it, and on the upper wall, another, transversely oval and larger (*fovea semi-elliptica*). These are separated by a small *pyramidal eminence*.

Fig. 134.

Osseous labyrinth of the left side. *o.* Fenestra ovalis, leading into the cavity of the vestibule. From this a bristle, †, is passed into *v v*, the vestibular scala of the cochlea, which is laid open in part by the removal of the outer wall. *r.* Fenestra rotunda, seen almost in profile. Through this a bristle, ‡, is passed into the tympanic scala of the cochlea, *t t*, exposed by the removal of part of the membranous portion of the lamina spiralis. The three semicircular canals are seen, with their extremities entering the vestibule, and one end of each dilated into an ampulla. Magnified 3½ diameters. Partly from Sœmmerring.

2. The *semicircular canals* are three in number, all opening at both ends into the vestibule, so that there would be six orifices, were not one of the orifices common to two of the canals. The canals are of unequal length, but all describe more than half a circle, and their cavity is not cylindrical, but slightly compressed on the sides, and about a twentieth of an inch in diameter. Each is dilated at one end into an *ampulla*, of more than twice the diameter of the tube, and at the opposite end it opens out slightly on entering the vestibule. Each canal lies in a different plane, the direction of which being constant, should be carefully noticed in relation to their function. The *superior vertical* canal is also *anterior*, and lies across the petrous bone. It forms about two-thirds of a circle, and its extremities are more divergent than those of the others. In the fœtus the concavity of this canal is free, owing to a deficiency in the substance of the petrous bone, and its arch forms a projection within the cranium, even in the adult. The ampulla is on its outer extremity. The *inferior vertical* canal is also *posterior*, and runs parallel to the posterior surface of the petrous bone, and therefore at right angles to the former. The ampulla is at its lower extremity, and its upper end joins

the inner end of the former canal, to constitute a common canal an eighth of an inch long, rather wider than those which join to form it, and opening behind and below. The *horizontal* canal is also *inferior*, and shorter than either of the others; its arch is directed outwards and backwards; its ampullar extremity is close to that of the superior vertical canal.

Fig. 135.

Interior of the osseous labyrinth. V. Vestibule. *a v.* Aqueduct of the vestibule. *o.* Fovea semi-elliptica. *r.* Fovea hemispherica. S. Semicircular canals. *s.* Superior. *p.* Posterior. *i.* Inferior. *a a a.* The ampullar extremity of each. C. Cochlea. *ac.* Aqueduct of the cochlea. *sv.* Osseous zone of the lamina spiralis, above which is the scala vestibuli, communicating with the vestibule. *st.* Scala tympani below the spiral lamina. From Sœmmerring.

3. The *cochlea* is, in shape, very like a common snail-shell. It lies almost horizontally, its apex forwards and outwards, its base marked near the bottom of the internal meatus, by a depression exhibiting a spiral arrangement of pores for the reception of the cochlear division of the auditory nerve. From base to apex extends the irregularly conical *axis*, *modiolus*, or *columella*, which is perforated by numerous branching channels, ascending from the pores just mentioned, and distributing the nervous filaments in regular succession within the spiral cochlear canal which winds around the axis. This *spiral canal* is about an inch and a half in length, if measured along its outer wall, and diminishes gradually in size from the base to the summit of the cochlea, where it ends in a cul-de-sac. At its commencement it is about one-tenth of an inch in diameter, but at its termination scarcely half that size. At its base it diverges somewhat from the modiolus, towards the tympanum and vestibule, and presents three openings. Of these, one, free and oval, enters the vestibule; another is the fenestra rotunda, communicating with the tympanum in the dry bone, but filled up in the recent state by a proper membrane, the *membrana tympani secundaria;* the third is the minute orifice of the *aqueductus cochleæ*, a funnel-shaped canal leading to the jugular fossa,

and supposed to transmit a small vein. The spiral canal describes about two turns and a half, of which the first, passing round the large base of the modiolus, takes much the widest sweep, so as to encircle most of the second turn. The inner wall of this coiled canal, as has been shown by Ilg, forms the outer wall of the modiolus.

The spiral canal of the cochlea is subdivided into two passages by an osseo-membranous lamina, extended between its modiolar and peripheral wall, and of course taking the same spiral direction as the canal itself. This is the *lamina spiralis*, the fundamental element of the cochlea, on which the nervous tubules are spread out. More than half its breadth on the side of the modiolus is formed by a very brittle osseous process from the modiolus, called the *osseous zone*, enclosing minute channels continuous with those of that part, and transmitting the nerves; its opposite or outer portion is membranous and muscular, and connects the outer thin edge of the osseous zone to the outer wall. The osseous zone commences gradually within the vestibule, and enters the spiral canal between the vestibular and tympanic openings of the cochlea, forming, with the help of the membranous extension, a complete septum between them. The passages, or *scalæ*, into which the spiral lamina divides the canal, correspond, therefore, respectively to those chambers; the upper, towards the apex of the cochlea, *scala vestibuli*, the lower, towards its base, *scala tympani*. These scalæ are, on the whole, pretty equal in size; the vestibular scala is, however, the smaller at the base, the tympanic, near the apex, of the coil; and the latter ceases ere it reaches the summit. At the apex of the cochlea the parts have an arrangement difficult to describe, though easily understood when seen. The axis, no longer hollow, and containing nerves, is reduced to a delicate lamella at about half a turn from the dome-like summit, or *cupola*, formed by the last part of the spiral canal. This lamella, which is the real apex of the modiolus, immediately expands, stretches upwards, and becomes more twisted on itself, so as to include part, or all of the last half turn of the cochlear canal, being termed from its appearance as viewed from below, the *infundibulum*, or funnel. The wide part of this imperfect funnel is directed towards the cupola, with which it blends. It is not open above, but on the side, and it is, in fact, the outside of the last half turn of the canal, projecting into the turn below.

The osseous zone of the spiral lamina ceases with the hollow modiolus at the slender lamella already mentioned, terminating by a small projecting hook (*hamulus*), the concave border of which is free, and directed towards the lamella, so as to leave an opening or deficiency, the *helicotrema* of Breschet, by which the scalæ tympani and vestibuli communicate. The membranous zone connects the convex border of the hook to the outer wall, and is also continued upwards beyond the point of the hook, presenting, however, towards the infundibulum, like the hook itself, a free concave border, contributing to form the orifice of communication.

Such being the form of the osseous labyrinth, we may now proceed to consider the more delicate parts of the organ, and the imme-

distribution of the auditory nerves. We must premise that the ty of the osseous labyrinth is occupied by a limpid fluid, the *ymph*, so called by De Blainville, from its surrounding, though e vestibule and semicircular canals only, a hollow membranous ratus, the *membranous labyrinth*, which latter itself contains a lar fluid, the *endolymph*.

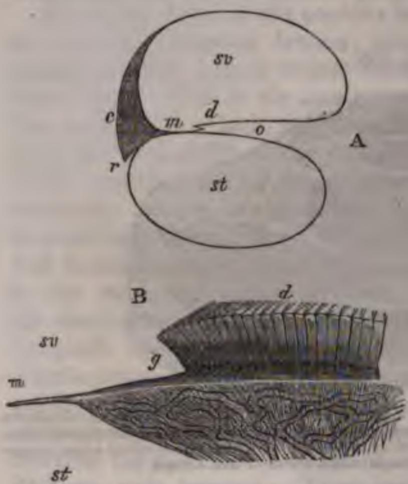
Fig. 136.

hlea of a new-born infant, opened on the side towards the apex of the petrous bone. It shows neral arrangement of the two scalæ, the lamina spiralis, and the distribution of the cochlear At the apex is seen the modiolus expanding into the cupola, where the spiral canal termi- in a cul-de-sac. The helicotrema is not visible in this view. From Arnold.

f the Structure of the Spiral Lamina of the Cochlea.—We shall the two surfaces of this lamina tympanic and vestibular, as they rd respectively the tympanic or vestibular scala. The *osseous* ion of the spiral lamina extends more than half way from the iolus towards the outer wall, and is perforated, as already de- ed, by a series of plexiform canals for the transmission of the lear nerves; these canals, taken as a whole, lie close to the r or tympanic surface, and open at or near the margin of this . The *vestibular surface* of the osseous zone presents in about outer fifth of its extent, a remarkable covering, more resembling texture of cartilage than anything else, but having a peculiar ngement quite unlike any other with which we are acquainted. g uncertain respecting the office of this structure, we shall term e *denticulate lamina* (figs. 137, and 138), from a beautiful series eeth, forming its outer margin, which project free into the ves- lar scala, and, in the first coil, terminate almost on a level with margin of the osseous zone, but more within this margin towards apex of the cochlea. They thus constitute a kind of second gin to the osseous zone, on the vestibular side of the true margin, having a groove beneath them, which runs along the whole na spiralis, in the vestibular scala, immediately above the true gin of the osseous zone. The intervals between the teeth are to een on their upper surface, on their free edge, and also within groove, so that the teeth are wedge-shaped, and their upper under surfaces, traced from the free edge, recede. The free ecting part, or teeth of the denticulate lamina form less than a th of its entire breadth, and in the remainder of its extent it ap-

pears to rest on the osseous zone; seen from above, after the osseous zone has been rendered more transparent by weak hydrochloric acid (fig. 138), rows of clear lines may be traced from the teeth at the convex edge, towards the opposite or concave edge of the lamina. These lines appear to be a structure resembling that of the teeth themselves, and they are separated from one another by rows of clear, highly refracting granules, which render the intervals very distinct. These intervals, as seen in the figure, are more or less sinuous and irregularly branched.

Fig. 137.



A. Section of the cochlear canal, where the scalæ are equal. *sv.* Scala vestibuli. *st.* Scala tympani. *o.* Osseous zone of lamina spiralis. *d.* Denticulate lamina. *m.* Membranous zone. *c.* Cochlearis muscle. *r.* Osseous rim of the groove of the cochlearis.
B. Margin of osseous zone, more magnified. *sv.* Scala vestibuli. *st.* Scala tympani. *g.* Groove, between *d,* denticulate lamina, and *m,* membranous zone springing from edge of the osseous zone. *n.* Cochlear nerves and capillaries, distributed on the tympanic surface of the osseous zone.

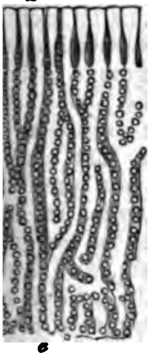
The denticulate lamina, thus placed on the vestibular surface of the osseous zone, is above, and at some distance from the plexus of the cochlear nerves, which lie near its tympanic surface. The vestibular surface of the osseous zone, including the denticulate lamina, is convex, rising from the free series of teeth towards the modiolus.

In the groove already mentioned there is a series of elongated bodies, not unlike columnar epithelium, in which the nuclei are very faint. These bodies are thick and cubical at one end, and taper much towards the other. They are united in a row; and it is possible they may have some analogy to the club-shaped bodies of Jacob's membrane. We can assign them no use.

Continuous with the thin margin of the osseous zone is the *membranous zone.* This is a transparent glassy lamina, having some resemblance to the elastic laminæ of the cornea, and the capsule of the lens. A narrow belt of it next the osseous zone is smooth, and exhibits no internal structure, while in the rest of its width it is marked by a number of very minute straight lines, radiating outwards from the side of the modiolus. These lines are very delicate at their commencement, become more strongly marked in the middle, and are again fainter ere they cease, which they do at a curved line on the opposite side. Beyond this the membranous zone is again clear, and homogenous, and receives the insertion of the cochlearis muscle. The *inner clear belt* of the membranous zone is little affected by acids. It seems hard and brittle. The middle or *pectinate portion* is more flexible, and tears in the direction of the lines. The *outer clear belt* is swollen, and partially destroyed by the action of acetic acid. Along

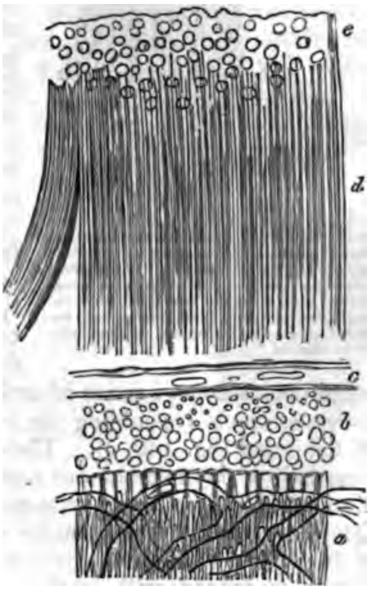
r clear belt, and on its tympanic surface, runs a single some-ranched vessel, which would be most correctly called a capa-apillary, as it resembles the capillaries in the texture of its it exceeds them in size. It is the only vessel supplied to the nous zone, and seems to be thus regularly placed, that it may the perfection of the part as a recipient and propagator of s vibrations.

Fig. 138.



te lamina of the os- of the lamina spira- . the vestibular sur- se edge of the teeth, separated by fissures a line b. The clear intervening rows of e seen at d. e. Mar- is the axis of the From the sheep.— 100 diameters.

Fig. 139.

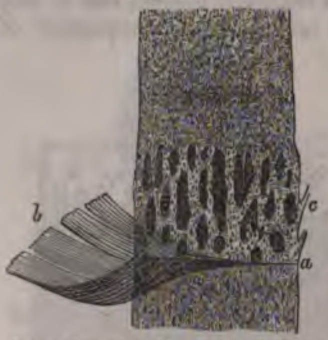


Tympanic surface of a portion of the lamina spiralis of the cat. *a.* Termination of the cochlear nerves at the border of the osseous zone, with capillaries ramifying over them. *b.* Inner clear belt of the membranous zone. *c.* Marginal capillary on the tympanic surface. *d.* Pectinate portion of the membranous zone. The half-detached fragment on the opposite edge shows its mode of tearing. *e.* Outer clear belt of membranous zone, torn from the cochlearis muscle. Magnified 300 diameters.

he Cochlearis Muscle.—At its outer or convex margin, the nous zone is connected to the outer wall by a semi-transparent e. This gelatinous looking tissue was observed by Breschet, ndeed very obvious on opening the cochlea; but we are not of any one having hinted at what we regard to be its real The outer wall of the cochlear canal presents a groove, ng the entire coil, opposite the osseous zone of the lamina and formed principally by a rim of bone, which, in section, ke a spur (fig. 137, *r*), projecting from the tympanic margin groove, the opposite margin being very slightly or not at all . This groove diminishes in size towards the apex of the . It gives attachment to the structure in question, by means

of a firm dense film of tissue, having a fibrous character, and the fibres of which run lengthwise in the groove, and are intimately united to it, especially along the projecting rim. From this *cochlear ligament*, the cochlearis muscle passes to the margin of the membranous zone, filling the groove, and projecting into the canal, so as to assist in dividing the tympanic and vestibular scalæ from one another, and thus forming in fact the most external, or the *muscular zone* of the spiral lamina. Thus the cochlear muscle is broad at its origin from the groove of bone, and slopes above and below to the thin margin in which it terminates, so that its section is triangular, and it presents three surfaces, one towards the groove of bone, and one to each of the scalæ. The surface towards the vestibular scala is much wider than that towards the tympanic scala, and presents, in a band running parallel to, and at a short distance from the margin of the membranous zone, a series of arched vertical pillars, with intervening recesses, much resembling the arrangement of the musculi pectinati of the heart (fig. 140, *c*). These lead to and terminate in the outer clear belt of the membranous zone, which forms a kind of tendon to the muscle. This entire arrangement is almost sufficient of itself to determine the muscular nature of the structure. If its fibres were of the striped variety, no doubt would remain; but its mass, evidently fibrous, is loaded with nuclei, and filled with capillaries, following the direction of the fibres, and in almost all respects it has the closest similarity to the ciliary muscle of the eye. The nuclei diminish in number as the fibres end in the tendinous part; and they are made much more evident by the addition of acetic acid. The action of the muscle must be that of making tense the membranous portion of the lamina spiralis, and so perhaps of adjusting it to the modifications of sound. As the ciliary muscle, though of the unstriped variety, adjusts the transparent media of the eye to distinct vision at different distances under the guidance of the will, so it is not impossible that the cochlear muscle may have a voluntary adjusting power, though its precise mode of action as a part of an acoustic apparatus may still remain obscure. On the whole, however, we are more disposed to regard this very interesting structure as having a preservative office, as being placed there to defend the cochlear nerves from undue vibrations of sound, in a way analogous to that in which the iris protects the retina from excessive light. These nerves are acted on principally by vibrations brought through the osseous part of the cochlea, and it is probable that the arrangement of the scalæ is one designed to allow of protective movements of the lamina spiralis by

Fig. 140.



Inner view of cochlearis muscle of the sheep. *a*. Line of attachment of membranous zone of lamina spiralis, of which a portion, *b*, remains attached. The surface below this line is in the scala tympani, the surface above, in the scala vestibuli. *c*. Projecting columns, with intervening recesses, in the vestibular part of the cochlearis muscle.

lar action, under a stimulus reflected from impressions on the ry nerve.

capillaries of the ciliary muscle are derived from vessels ering over the walls of the scalæ before entering it, and from above and below do not anastomose across the line of nent of the membranous zone, thus indicating that the con-on of this zone enters as a plane of tendon into the interior of uscle, dividing it into two parts, and receiving the fibres in sion.

scalæ of the cochlea are lined with a nucleated membrane, or ium, which is very delicate and easily detached, usually more seen in the vestibular than in the tympanic scala, and in many s containing scattered pigment.

the Cochlear Nerves.—These enter from the internal auditory through the spirally-arranged orifices at se of the modiolus, and turn over in suc- into the canals hollowed in the osseous f the spiral lamina, close to its tympanic :. In this distribution the nervous bundles ide and reunite again and again, forming :us with elongated meshes, the general ng arrangement of which can be readily rough the substance of the bone when it has steeped in diluted hydrochloric acid (fig. Towards the border of the osseous zone the s of the plexus are smaller and more closely as at length almost to form a thin uniform f nervous tubules. Beyond the border, rtially on or in the inner transparent belt membranous zone, these tubules arrange lves more or less evidently into small sets, advance a short distance and then termi-ach on the same level. These terminal tubules are cone-shaped, coming to a kind t ere they cease. The white substance of on exists in them throughout, but is thrown ricosities and broken with extreme facili- . they are interspersed with nuclei, so that ry difficult to discover the precise dispo- of the individual tubules (fig. 139, *a*). seem to cease one after another, thus the set to taper; and at least it appears that evidence of loopings, such as have lescribed by some, is wanting. In the cochlea of the bird, er, we have seen at one end a plexiform arrangement of nucle- res ending in loops; but this is a peculiar structure.

Fig. 141.

Plexiform arrangement of the cochlear nerves seen in the basal coil of the lamina spiralis, treated with hydrochloric acid. There are no ganglion globules in this plexus, which consists of tubular fibres. *a*. Twig of cochlear nerve in the modiolus, its fibres diverging and re-uniting in *b*, a band in the plexus taking a direction parallel to the zones. From this other twigs radiate, and again and again branch and unite as far as the margin of the osseous zone *c*, where they terminate. From the sheep. Magnified 30 diam.

capillaries of the osseous zone are most abundant on the ic scala in connection with the nerves now mentioned, and ops near the margin, with here and there an inosculation with e marginal capillary already mentioned.

Of the Membranous Labyrinth (fig. 142).—This has the sam ral shape as the bony cavities in which it lies, but is consi smaller, so that the perilyn tervenes in some quantity, where the nerves passing to fine it in close contact w osseous wall. Its vestibul tion consists of two sacs, principal one of transverse figure and compressed la called the *utriculus*, or *sinus*, occupying the upp back part of the cavity, in with the fovea semi-ellipti beneath this a smaller an globular one, the *sacculus*, the fovea hemispherica, n orifice of the vestibular scal cochlea, and probably co cating with the utriculus.

Fig. 142.

Membranous labyrinth of the left side, with its nerves and otoliths:—*su.* Superior semicircular canal, with the ampulla and its nerve at one end, and the other end joined by *p*, the posterior canal, to form the *tubulus communis.* *i.* Inferior, or horizontal canal, with the ampulla and its nerve at one end, and the other entering the utriculus separately. *c.* Powdery otolith seen through the translucent wall of the common sinus, or utriculus, with the nerves distributed to it. *s.* Powdery otolith of the sacculus seen with its nerve, in a similar way. *n.* Cochlear division of the auditory nerve cut off where it enters the cochlea. *d. Portio dura* of the seventh pair leaving the auditory nerve, or *portio mollis*, to enter the aqueduct of Fallopius. Magnified. From Breschet.

The *membranous semi canals* have the same names and arrangement as the canals which enclose them, only a third of the diamete latter. As the osseous can into the vestibule, so the branous ones open at bo into the utriculus—there however, a constricted n tween this sac and the am extremity of each canal. The auditory nerve sends branche utriculus, to the sacculus, and to the ampulla of each mem canal. These nerves enter the vestibule by the minute a before described, and tie down, as it were, both the utricu sacculus to the osseous wall at those points, the membran much thicker and more rigid where the nerves join it. The b to the ampullæ of the superior vertical and the horizontal semi canals enter the vestibule with the utricular nerve, and then their destinations, while that to the ampulla of the posterior canal traverses the posterior wall of the cavity, and opens into the ampulla.

The wall of the membranous labyrinth is translucent, flexi tough. When withdrawn from its bed and examined, it ap present three coats, an outer, middle, and internal. The loose, easily detached, somewhat flocculent, and contains less colouring matter disposed in irregular cells, exactly res those figured at page 409, from the outer surface of the chor of the eye. We have not found a true epithelium on this The middle is the proper coat, and seems more allied to

any other tissue; its limits are well marked, it is transparent, ıibits in parts a longitudinal fibrillation: treated with acetic presents numerous corpuscles or cell-nuclei. Where it is it has a near resemblance to the hyaloid membrane of the 'he internal coat is composed of nucleated particles closely l and but slightly adherent; the nuclei are often saucer-shaped, en seen edgeways, have the uncommon appearance of a cres- They easily become detached, and fall into the endolymph. arteries and veins, derived chiefly from a branch of the ıccompanying the auditory nerve, enter the vestibule from the meatus, and ramify on the exterior of the membranous laby- pparently bathed in the perilymph. A beautiful network of ies, forcibly reminding the observer of that belonging to the is spread out on the outer surface and in the substance of the coat. These vessels have the simple homogeneous wall, rsed here and there with cell-nuclei, that characterizes the y channels in many other situations. There is an abundant of capillaries in the interior of the utriculus and sacculus he terminal distribution of the nerves, which evinces the of the function of these parts.

membranous labyrinth, or its simple representative the audi- , contains, in all animals, either solid or pulverulent calca- natter, in connection with the termination of the vestibular This has been called by Breschet *otolith*, or *ear-stone*, when s in the osseous fishes, and *otoconia*, or *ear-powder*, when in n of minute crystalline grains, as in mammalia, birds, and , but the former term may be conveniently employed to te both varieties. In the mammalia, including man, it is accumulated in small masses about the termination of the both in the utriculus and sacculus, and we have found it ıringly scattered in the cells lining the ampullæ and semicir- ınals. In the vestibular sacs, it appears to be entangled in a very delicate branched fibrous tissue, in connection with the ıd it is most probably held in place by cells within which, ıg to Krieger, (*De Otolithis*, Berol., 1840,) its particles are d. It has a regular arrangement, and is not free to change in the endolymph. Otoliths consist always of carbonate of

e Vestibular Nerves.—In consequence of the thickness of the the membranous labyrinth where the nerves enter, and the e there of the calcareous and fibrous matter, it is not easy to n with certainty the precise manner in which the nerves ter- In the utricle and saccule, they appear to spread out from ther as they enter, and then to pass, some to mingle with the ıus powder, others to radiate for a small extent on the inner of the wall of the cavity, where they come into connection layer of dark and closely-set nucleated cells, and presently ir white substance. We have seen a fibrous film on the inner of these parts, which we are disposed to consider as formed, inner surface of the retina, by the union of the axis-cylin-

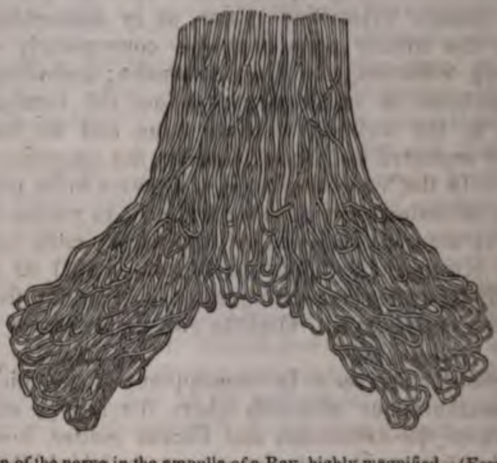
ders of the nerve-tubes, but confirmatory observations are required. Those that traverse the calcareous clusters have appeared to us, in the most lucid views we have succeeded in obtaining, to terminate by free, pointed extremities, without losing their white substance. In the frog this has been evident enough.

Fig. 143.

View of the nerves going to the membranous labyrinth:—*a*. Branch to the ampulla of one of the semicircular canals. It is seen perforating the wall and expanding transversely within. *b*. Semicircular canal cut across. From Steifensand.

The nervous twigs belonging to the semicircular canals do not seem to advance beyond the ampullæ, in which they have a remarkable distribution, entering them, as Steifensand has well shown, by a transverse or forked groove on their concave side, and which reaches about a third round. Within this, the nerve projects so as to form a sort of transverse bulge within the ampulla. Their precise termination can be best seen in the osseous fishes, and has been described by Wagner to be loop-like, as will be apparent from the adjoined figure. We believe we have seen

Fig. 144.



Termination of the nerve in the ampulla of a Ray, highly magnified. (From Wagner.)

this mode of termination, though certainly never so plainly as the figure given by this excellent author would indicate; and we may add that we have found free extremities to the nerve-tubes, as well as loopings, in the ampullæ of the cod. The difficulty in these cases of ascertaining the exact truth, arises from the curves formed by the nerve-tubes in proceeding to their destination, and which are liable to be mistaken for terminal loopings.

Of the Auditory Nerve.—The *portio mollis* of the seventh pair has its origin from the medulla oblongata by two roots. One penetrates into the central part of the medulla oblongata in the same way, and following the same direction, as the portio dura, but passing to a much greater depth into its substance. The other winds round the corpus restiforme, not penetrating it, but simply adhering to its surface, until it reaches the floor of the fourth ventricle, where it connects itself with the olivary columns, and in many instances is evidently continuous with the white striæ on either side of the calamus scriptorius, which for that reason have been very generally regarded as fascicles of origin of the portio mollis.

The portio mollis, when contrasted with the other nerves of the medulla oblongata, is remarkable for its delicacy of structure, a character which had attracted the attention of the older anatomists, and by reason of which they had given the nerve the appellation "mollis." It has but a very delicate neurilemma, and its fascicles are loosely held together; it seems strictly a direct prolongation of the white matter of the brain.

The portio mollis enters the internal auditory foramen, and there forms a connection with the portio dura, by means of a few fascicles of fibres which constitute the "portio intermedia" of Wrisberg. It is difficult to say whether this consists of fibres proceeding from the auditory to the facial nerve, or from the latter to the former. It is most reasonable to suppose that the muscular nerve (the facial) sends some filaments into the labyrinth to the blood-vessels, and to the muscular structure of that portion of the ear.

At the bottom of the meatus, the portio mollis divides into two branches, one to the vestibule and semicircular canals, the other to the cochlea.

The vestibular nerve divides into three branches:—the largest is uppermost, and penetrates the depression which is immediately behind the orifice of the aqueduct of Fallopius to be distributed to the utriculus, and to the ampullæ of the superior vertical and the horizontal semicircular canal. The second branch of the vestibular nerve is distributed to the sacculus, and the third to the posterior vertical semicircular canal.

The cochlear nerve penetrates the funnel-shaped depression at the bottom of the auditory canal, and proceeds from it through the numerous foramina, by which its wall is pierced, in a spiral manner, to the lamina spiralis of the cochlea.

The mode of distribution of these nerves has been already described.

The labyrinth receives nerves from no other source than the portio mollis, unless we suppose the portio intermedia to consist of filaments from the facial which accompany the ramifications of that nerve into that part of the ear.

That the *portio mollis* is the nerve of hearing is abundantly proved by the following arguments:—1. The distribution of the nerve to the internal ear, to which no other nerve of any importance is distributed. 2. Its softness of texture and cerebriform character dis-

tinguish it from ordinary nerves of sensation or motion. 3. Disease states of it, or of parts immediately near to its origin, affect the sens of hearing, whilst a paralytic state of the portio dura or of the fift does not affect the sense.

Of the Nervous Apparatus accessory to the Organ of Hearing.— Besides the auditory nerve there are others which influence the audi tory apparatus. These are branches of the portio dura, branches o the nerve of Jacobson, from the glosso-pharyngeal, and from the oti ganglion.

These nerves present a striking analogy with those which are dis tributed to the eye.

The tympanum receives branches from the facial, and glosso-pha ryngeal, and probably from the sympathetic.

The facial, in its passage through the aqueduct of Fallopius, give off the chorda tympani, which, however, seems to have no physiolo gical connection with the tympanum or its contents. The stapedi muscle receives a branch from the facial nerve. The anastomosis Jacobson results from the subdivision of the tympanic branch of th glosso-pharyngeal nerve, which enters the cavity of the tympanu below, and passing over the promontory, gives off branches to th membranes of the fenestræ, and Eustachian tube, and to the ot ganglion.

A branch is described by Arnold as proceeding from the ot ganglion to the tensor tympani muscle.

The external ear is supplied by the facial nerve as regards i muscular apparatus, and by the fifth pair as regards its sentient su faces.

The influence of the facial nerve upon the muscular apparatus the organ of hearing, whether tympanic or labyrinthic, is similar that of the third nerve upon the muscles of the eyeball, or upon th iris and ciliary muscle. And it seems probable that while voliti can exercise a certain influence upon the muscular apparatus hearing, that apparatus may likewise be excited to action throug the physical stimulus of sound affecting the auditory nerve, whic reacting upon the portio dura excites its fibres to a degree propo tionate to the intensity of the sound; as the stimulus of light affectin the optic nerve reacts upon the iris.

We shall now proceed to inquire into the office of each part of th complex organ of hearing.*

* The following points respecting the laws of sound should be borne in mind considering the offices of the various parts of that complex acoustic apparatus, t human ear.

1. Any irregular impulse communicated to the air will produce a *noise*; a succ sion of impulses occurring at exactly equal intervals of time, and exactly similar duration and intensity, constitutes a *musical sound*.

2. The frequency of repetition necessary for the production of a continued sou from single impulses is, probably, generally not less than sixteen times in a seco but Savart thinks that some ears may distinguish a sound resulting from only ten eight vibrations in a second. On the other hand, sounds are audible which con of 24,000 vibrations in a second.

3. Sound may be propagated or conducted by air, gases, liquids and solids, v various degrees of rapidity.

necessary for the reader to bear in mind that the organ of may be affected in two ways: first, through the external ear, ondly, through the bones of the head. Every person must ticed the difference in the sound of the ticking of a watch if ld near the ear but not in contact with it, and if it be held the teeth. The waning note of the vibrating tuning-fork evived when the stem of the fork is brought in contact with ı or with any part of the head. These differences are due ifference of the medium through which the sonorous undula- : made to affect the auditory nerve. In the former instance, is excited through the external ear, when the watch is held t part, and through the bones of the head, when the watch ht into contact with the teeth. And in the example of the ork, the sound appears to revive when it is made to affect ve through a medium (the bones of the head) which more vibrates in unison with the most delicate oscillations of the g body.

f *the External Ear.*—The external ear consists of two parts, *cle*, and the *meatus auditorius externus*. The complete de- nt of the former is found only in mammalia, in which class s pretty generally; with, however, considerable diversity of ırying from what appears to be little more than a mere carti- ı lamella with a few irregularities upon its surface, enjoying any motion, to an elongated funnel-shaped ear-trumpet, very le, and completely under the control of numerous large mus-

ıd travels through air at the temperature of 62° Fahr., at the rate of 1125 second.

ıd is incapable of transmission through a vacuum.

propagation of sound is the more effectively performed as the medium of ion is more dense. Rarefied air, gases of low density, and soft solids, are et conductors of sound than much denser materials of the same kind.

distinguish in sounds, 1, the *pitch*; 2, the *intensity* or *loudness*; 3, the *quality*

ch of the sound depends on the rapidity with which the vibrations succeed r, and any two sounds produced by the same number of vibrations or im- the same time, are said to be in unison.

udness or intensity depends upon the violence and extent of the primitive

ality is supposed by Herschel to depend on the greater or less abruptness pulses; or generally on the law which regulates the excursions of the mole- inally set in motion.

velocity with which sound travels is, however, quite independent of its or of its tone; sounds of every pitch, and of every quality, travel with the ed through the same medium, as is proved by the fact, that distance does y the harmony of a rapid piece of music played by a band.

er propagates sound with much greater velocity than air does. Colladon , from numerous observations, that the velocity of sound in water, at 40° s at the rate of 4708 feet in a second.

cording to Biot, cast-iron propagates sound at the rate of 11,090 feet in a

orous undulations, in passing from one medium to another, always ex- a partial reflection, and when they encounter a fixed obstacle, they are olly reflected. The reflection of sound occurs according to the same law ulates the reflection of light,—namely, the angle of reflection is equal to the ncidence.

e phenomena of echoes result from the reflection of sound from any promi- nt.

cles. Man and the quadrumana are at one extremity of this scale; the solipeds, the ruminants, and the bats at the other.

That the auricle performs the office of an acoustic instrument to collect and reinforce the sounds which fall upon it, cannot be doubted in those cases in which it is large and fully developed, as in the horse, ass, &c. These animals employ it as we might expect such an instrument would be used; the open part is directed towards the quarter whence the sound comes, and continues so directed as long as the animal appears to listen.

Savart's experiments illustrate the manner in which an instrument like the external ear may contribute to the propagation of sound to the internal ear. When a thin membrane is stretched in a horizontal direction over the mouth of a glass or other hollow vessel, it may be made to vibrate by holding near it a glass thrown into vibration by passing a violin bow across it. The vibrations of the paper are easily demonstrated by the movements of particles of fine sand, or lycopodium powder strewed upon it. The sand arranges itself in certain very definite figures, the shape of which is determined by the position of the lines of repose, or *nodal lines*, over which the sand accumulates. These phenomena may be shown in the membrana tympani itself, by scattering a little sand upon it, the osseous meatus having been previously cut away. When the vibrating glass is brought near to it, the movement of the particles of sand affords sufficient evidence of the vibration excited in the tympanic membrane, but owing to the slight extent of the membrane it is impossible to determine the existence of any nodal line.

Savart imitated the tympanic membrane, and the external auditory apparatus by a hollow cone of paste-board; across the narrow extremity some thin paper was stretched. When the vibrating glass was brought near to the narrow end, movements of a slight kind were excited in the paper, but when the glass was brought to the wide extremity of the cone, much more extensive movements were excited in the paper; although now the glass was much more distant from the paper than previously.

This result might have been due chiefly to one of two causes, namely, either to the concentration of the sonorous undulations by the walls of the cone, or to the excitation of vibrations in the walls of the tube, which would be propagated directly to the paper; and Savart showed by the following simple experiment that the latter cause was obviously the most effective. He prepared a second conical tube open at both ends, and having placed the narrow end of this tube very near the paper on the former one, but not *in contact with it*, he found that vibrations were excited on the paper by bringing the vibrating glass near to the wide end of the second tube, but that these vibrations were not nearly so extensive as when the glass was brought near to the wide extremity of the tube with which the paper was connected.

Hence Savart inferred that the external ear and meatus were par[tly] adapted to enter into vibrations in unison with those of the air, or any liquid or solid vibrating medium which might be brought in co[ntact]

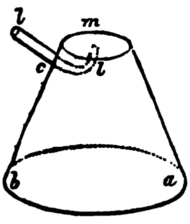
tact with the auricle; and he suggested that the latter part, in the human subject, by the variety of direction and inclination of its surfaces, could always present to the air a certain number of parts whose direction is at right angles with that of the molecular movement of that fluid, and therefore in the most favourable circumstances for entering into vibration with it.

We get a general notion of the value of the external part of the auditory apparatus in collecting and directing the sonorous undulations, from the assistance often derived in hearing by placing the hand behind the external ear, so as to increase its concavity; and by the dulness of hearing, which it is said follows the loss of the auricle. Kerner states that the loss of the auricle is followed by the greatest dulness of hearing in those animals in which the osseous meatus is wanting. In a cat from which the right ear was cut away close to the skull, after the wound had healed without any stoppage of the meatus, there was a remarkable disposition always to keep the head turned so as to be ready to receive sounds with the left ear, and this continued even after the left tympanic membrane was perforated, the right remaining whole; and when the left ear was stopped, (although the right tympanic membrane was sound, and the only injury on that side was the removal of the auricle,) a total deafness was manifested except to the loudest and clearest sounds.

The Tympanum and its Contents.—We have already stated that Savart had demonstrated experimentally upon the membrana tympani itself, that that membrane can be thrown into vibrations by undulations of the air excited by a sonorous body. In a second experiment, the cavity of the tympanum was opened, so as to expose the ossicles of the ear and their muscles; and it was observed that when the internus mallei muscle acted and rendered the membrane tense, it was much more difficult to produce manifest movements in the grains of sand; thus affording much reason to suppose that the tensor tympani muscle is analogous in its use to the iris, and destined to protect the organ from too strong impressions. These experiments can be best tried on the membrana tympani of the calf.

In imitation of the mechanism by which the tension of the membrana tympani is effected, and with a view to determine more decisively the effects produced by variation of the tension of that membrane, Savart constructed a conical tube (fig. 145), with its apex truncated and covered by a layer of very thin paper, *m*, which was glued to the edge of the opening. A little wooden lever, *l*, *l*, introduced through an opening in the side of the tube, and resting on the lower margin of this opening, *c*, as a fulcrum, was used to vary the tension of the membrane, one of its extremities being applied to the under surface of the membrane. By depressing the extremity of the lever external to the tube, the inner one is raised, and thus the membrane stretched to a greater or less degree, according to the force used; on the other hand, by elevating the outer extremity, the

Fig. 145.



inner one is separated from the membrane, which is accordingly restored to its original tension. This little lever is an imitation of the handle of the malleus, which, under the influence of its muscles, causes the variation in the tension of the membrana tympani. The artificial tympanic membrane having been then covered with a layer of sand, it was found, that, under the influence of a vibrating glass, used as in the former experiments, a manifest difference was produced in the movements of the grains of sand, by increasing the tension of the paper; the greater the tension, the less the height to which the grains of sand were raised; and these movements were most extensive when the lever was withdrawn from contact, and the membrane left to itself.

From these experiments Savart concludes that the membrana tympani may be considered as a body thrown into vibration by the air, and always executing vibrations equal in number to those of the sonorous body which excites the oscillations of the air. But what is the condition of the ossicles of the tympanum whilst the membrane is thus in vibration? The result of the following experiment affords a clue to the answer to this question. To a membrane stretched over a vessel, as in fig. 146, a piece of wood, *a*, *b*, uniform in thickness,

Fig. 146.

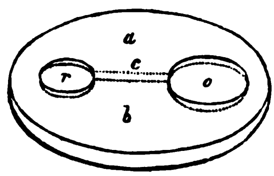
Fig. 147.

is attached, so that the adherent part shall extend from the circumference to the centre of the membrane, while the free portion may project beyond the circumference. When a vibrating glass is brought near this membrane, very regular figures are produced, modified, however, by the adhesion of the piece of wood, and the vibrations of the membrane are communicated to the wood, on which likewise regular figures may be produced. The more extensive the membrane, the longer and thicker may be the piece of wood in which it can excite oscillations, and Savart states that, with membranes of a considerable diameter, he has produced regular vibrations in rods of glass of large dimensions. The oscillations of the piece of wood are much more distinct when the adherent portion is thinned down, as in *c*, *d*, fig. 147, by which it becomes more completely identified with the membrane; the oscillations of this latter are communicated directly to the thinned portion of the wood, and thence propagated to the thick portion, *a:* sand spread upon *a* will exhibit active movements, and will indicate very distinct nodal lines. Hence it may be inferred that the malleus participates in the oscillations of the tympanic membrane; and these vibrations must be propagated to the incus and stapes, and thus to the membrane of the fenestra ovalis. The chain of ossicles then evidently performs the office of a conductor

: oscillations from the membrana tympani to the membrane of the nestra ovalis; but the malleus likewise has the important function nder the influence of its muscles of regulating the tension of the mpanic membrane; and to allow of the changes in the position of is bone necessary for that purpose, we find it articulated with the cus by a distinct diarthrodial joint, and between this latter bone gain and the stapes there exists another and a similar joint. This obility then of the chain of bones, and the muscular apparatus of e malleus and stapes have obvious reference to the regulation of e tension of the membrane of the tympanum as well as of that of e fenestra ovalis.

We have already seen how the muscle of the malleus regulates the embrana tympani, increases its tension, and thus limits the extent f the excursions of its vibrations. The contraction of the stapedius uscle causes the base of the stapes to compress the membrane of the nestra ovalis to a greater or less extent, so that the degree of tension of that membrane depends on the condition of this muscle. ompression exerted upon the membrane of the fenestra ovalis extends to the perilymph, and through it is propagated to the membrane f the fenestra rotunda, and in this way the same apparatus which gulates the tension of the membrane of the fenestra ovalis performs at office for that of the fenestra rotunda, and Savart has devised an pparatus which very prettily illustrates the manner in which this ay take place. In a disc of wood (*a*, , fig. 148) of sufficient thickness, he ollows out two cavities, *o* and *r*, which ommunicate at their bottoms with each ther by a narrow canal (*c*) hollowed in e wood, but not open on its surface; thin membrane is extended over each f the cavities. Thus, the air contained these cavities may pass easily from ne to the other, and may always maintain the same degree of elastic nsion in both. If a vibrating glass be brought near the membrane , covered with a layer of sand, it will be found to enter freely into ibration, as evinced by the active movements of the grains of sand. f, now, pressure be made on *o* with the finger, *r* will become convex n proportion as *o* is rendered concave by the pressure, and when in his convex state, the movements of the sand upon it will be much ess considerable than before, presenting an effect precisely similar to hat produced on the tympanic membrane by an increase of tension. Thus, the extent of the excursions of the vibrations of the membrane , is limited by the pressure exerted upon *o*, and as the membranes f the two fenestræ are related to each other in an analogous manner, e may argue that pressure upon the membrane of the fenestra ovalis ill occasion tension of that of the fenestra rotunda, thereby limiting e extent of the excursions of its vibrations.*

Fig. 148.



* All these experiments have been frequently repeated and exhibited by us, with e same results as those stated in the text.

Moreover it appears, upon reference to the anatomy of these parts, that the only muscles which have been satisfactorily demonstrated are *tensors* of the tympanum; and that at whichever extremity of the chain of ossicles muscular effort be first exerted, a corresponding effect will be produced at the other; that when the stapedius muscle acts, the malleus is thrown into a position favourable to the tension of the membrana tympani, and, on the other hand, the contraction of the internus mallei depresses the stapes, and consequently increases the tension of the membranes of the two fenestræ. The cessation of muscular action restores all three membranes to their original laxity, nor does it appear that they admit of any further degree of relaxation through the influence of any vital process. The incus forms a bond of union between the two other bones, and its motions depend entirely upon theirs in consequence of its articulation with both, while from the fixedness of its connection with the mastoid cells, as well as from its intermediate position and want of muscular attachment, its motions must obviously be much more limited than those of the other bones. Its use seems to be to complete the chain in such a manner, that by reason of its double articulation with the malleus on the one hand and the stapes on the other, the tension of the tympanic membranes may be regulated without any sudden or violent motion, which could scarcely be avoided were the conductor between the membranes of the tympanum and fenestra ovalis but one piece of bone.

The mobility of the tympanic bones has, however, a further use, as Müller suggests; namely, to favour the oscillations of the membrana tympani, by allowing the approximation of the two extremities of the chain of bones. And this opinion is strengthened by the facts of comparative anatomy, for the ossicles have moveable articulations in the frog, as in man, although they have no muscles attached to them.

The addition of a cavity filled with air outside the labyrinth has a twofold use. First, to preserve uniformity of temperature in the air immediately in contact with the fenestral membranes. Were these membranes situate on the exterior of the head, and exposed to the surrounding atmosphere, they would be constantly undergoing changes in their elastic state, under the influence of atmospheric vicissitudes. The air which accumulates in the tympanum and mastoid cells, finds its way into them only through the Eustachian tubes, and as it does not readily change its position, it is well placed for maintaining a temperature equal to that of the body. Secondly, the action of the chain of ossicles as conductors is materially enhanced by their being completely surrounded by air. The insulation of a solid body by a different medium renders it a better propagator of sound; for the surrounding medium will obviate the dispersion of sound, and will favour its retention in the solid conductor.

It results from Savart's experiments, that tension of the membrana tympani is unfavourable generally to the propagation of sounds, especially of those of a low pitch. By rendering the membrana tympani tense in one's own person, the correctness of this statement may be readily ascertained. In blowing the nose forcibly, air is forced into the tympanum, and its membrane is rendered convex and tense, and

ıe must have experienced the temporary deafness which re-ıfter such an effort. The tympanic membrane may also be l tense by forced inspiration, the nose and mouth being kept Jnder these circumstances the tympanic cavity is exhausted, membrane rendered tense by the pressure of the external air. scending in the diving bell, the membrane of the tympanum red painfully tense by the increased pressure of the air, and t of counter pressure from within. This tension may be so even to cause rupture of the tympanic membrane in some ut it may be obviated by acts of swallowing, during which rnal air is driven into the tympana along the Eustachian tubes. the tense state of the membrane, hearing is impaired; M. n found that the voices of his companions and of himself were istinctly heard.

Vollaston performed many experiments upon the effects of of the membrana tympani, and he found that deafness to otes was always induced, which, as most ordinary sounds a low pitch, is tantamount to a general deafness. Shrill however, are best heard when the tympanic membrane is Müller remarks, and we have frequently made the same ob-n, that the dull rumbling sound of carriages passing over a or of the firing of cannon, or of the beating of drums at a , ceases to be heard immediately on the membrana tympani ıg tense; while the treading of horses upon stone pavement, e shrill creaking of carriages, and the rattling of paper, may ıctly heard.

ıbject of the Eustachian tube is chiefly to allow the free in-air into the tympanic cavity, in order to provide for the due ı of the membrana tympani and of the chain of bones. It permitting a free *egress* of air, renders the tympanum a non-ating cavity, and therefore obviates the production of echoes hich would materially interfere with perfect hearing. The ıce of the Eustachian tube to the integrity of hearing is well o all practical men, by the deafness which always accompa-onic or acute disease of the tonsils, or occlusion of the canal ube from any other cause.

dea of Boerhaave, and of Bressa, that sounds from without nter the mouth, or the sounds of one's own voice, were con-ıy the Eustachian tube to the labyrinth, is disproved by the xperiment of holding a sounding tuning-fork or a watch in mouth, when it will be always found, if due care be taken to ıntact, that the sounds proceeding from them are not so well those from without, and the nearer they are brought to the ian tube the less distinctly are they heard. Indeed it may be ıoticed that persons deaf from obstruction of the Eustachian ır the sounds of their own voices well.

e Labyrinth.—The essential part of the organ of hearing is *ibule.* This is sufficiently proved by the constancy of this he animal series, and by its central position in the most com-

plex ears, so that it is in close relation not only with the other parts of the labyrinth, but also with the tympanum.

Sound is conveyed to the labyrinth in a threefold manner: first, by the chain of bones; secondly, by the air in the tympanic cavity; in both these instances the external air is engaged in the conduction; and thirdly, through the bones of the head.

Müller has shown, by a very interesting experiment, that, whilst the air in the tympanum conducts sound to the cochlea through the fenestra rotunda, the chain of bones forms a much better conductor of it to the vestibule through the fenestra ovalis. He imitated the structure of the tympanum by means of a glass cylinder, two inches and one-third in diameter, and six inches long; to the neck of this he fixed a wooden tube, the diameter of whose bore was eight lines. The upper end of this tube was adapted to the mouth of the metal flute-pipe of an organ, one foot in length; its lower extremity was covered with a tense membrane of pig's bladder, which represented the membrana tympani, the tube itself corresponding to the meatus externus, and the cavity of the glass cylinder to the tympanum. The lower opening of the glass cylinder was closed by a thick piece of cork, in which two holes were cut equidistant from the walls of the cylinder. In these holes, which represented the fenestræ, two wooden tubes were fitted, whose outer openings were covered with membrane. From the membrane of the upper tube to one of these membranes, a rod was extended to imitate the chain of tympanic bones extending between the membrane.

The lower extremity of this apparatus (that, namely, which was fitted with cork) was now introduced into water, to imitate the connection between the tympanum and the labyrinth in which sound is conducted from air to liquid. Müller, having plugged his ears, could by means of a sounding-rod applied in succession to the membrane of each of the artificial fenestræ, ascertain the relative intensity of the sonorous vibrations communicated to the water through the two openings, while another person sounded the pipe. He states that the difference was very striking. The sound transmitted by the wooden rod to the opening which represented the fenestra ovalis, was in a remarkable degree louder than that propagated through the air of the cavity to the membrane of the other opening.

The results of this experiment lead to the conclusion (which other circumstances confirm), that the vestibule is adapted to receive sound from the tympanic membrane and external ear, while the cochlea is not easily affected in this manner, but rather, as its structure and connections point out, that it is fitted to receive vibrations through the bones of the head.

The direct continuity of the walls and the septum (*lamina spiralis*) of the cochlear canal, with the petrous bone, and the minute subdivision of the nerve in distinct canals in the osseous substance, render that portion of the labyrinth most readily affected by the vibrations excited in the cranial bones. The cochlea may therefore be properly considered as that part of the labyrinth which is more immediately affected by sounds communicated through the bones of the head, a

stibule is the part primarily affected by the sounds communi- through the external ear.

ıay be easily shown by some experiments with the tuning-fork, nly that the cranial bones do conduct, but also that sounds ble, or imperfectly audible, through the meatus externus, may tinctly heard when the sounding body is brought into contact bone of the cranium or face. When the tuning-fork is thrown ibration by striking it against any solid body, if held near the ıal ear its vibrations are distinctly heard, but let the stem be d to the teeth, or to the upper jaw, or to the parietal bone, ıe sound appears much louder; or if the fork be held near the til the sound has almost died away, and then its stem be ap- to the superior maxilla, or to the teeth, the sound seems to ı, and continues for a considerable period while the stem is n contact with the bone.

: form of the cochlea probably has reference to the convenient ge within the smallest compass of the great number of nerve which proceed to it.

ı remarkable subdivision which the cochlear nerve undergoes, ibly adapts it for the reception of vibrations communicated h the cranial bones. "The spiral lamina of the cochlea," says r, "must be regarded as a surface upon which all the fibres of chlear nerve are spread out, so as to be nearly simultaneously ed to the impulse of the sonorous undulation, and simultaneously n into the maximum state of condensation, and again into the mum state of rarefaction." "This spreading out of the nerve upon the lamina spiralis, insures a more complete participation fibres in the impulses communicated by the solid parts of the a." Moreover, "the intensity with which sonorous undula- ıre communicated to a body, is proportionate to the extent of over which they can act on it. Thus, when a sound is ex- in water, and is conducted to the stopped ear by means of a he intensity of the sound heard increases with the depth to the rod is immersed in the water, or with the extent in which contact with the surface of the water."*

fluid in the scalæ of the cochlea, with the helicotrema or orifice mmunication, must facilitate the vibrations of the lamina spiralis, e have already assigned to the cochlearis muscle a protective the cochlear nerves.

Otoliths.—The earthy particles, which, either as pulverulent s, or as hard porcelainous stones, are connected with the nerves membranous labyrinth, must reinforce the sonorous undula- and communicate to the membranous labyrinth and its nerves ory impulses of greater intensity than the perilymph alone could t. In illustration of this, Müller mentions that sonorous undu- r in water are not perceived by the hand itself immersed in the but are felt distinctly through the medium of a rod held in the

ller's Physiology, by Baly, vol. ii. p. 1294. Dr. Young regarded the cochlea ierometer of sound.

hand. The experiment of Camper is also illustrative. Fill a bladder with water and place a stone or some other hard body in it. The slightest impulse communicated to the bladder disturbs the stone, which consequently produces a greater impression on the hand by which the bladder is supported.

The Semicircular Canals.—There is nothing known of the function of the semicircular canals. Yet their almost constant existence, and nearly constant number evince their physiological importance. In most cases of congenital deafness they are found defective.

Their constancy in the higher animals of number, and of position, which is such that they correspond to the three dimensions of a cube, its length, breadth, and depth, suggested to Autenrieth and Kerner the opinion that they are the parts concerned in conveying a knowledge of the direction of sounds, a view which is also advocated by Wheatstone. The latter philosopher conceives that we distinguish best the direction of those sounds which are sufficiently intense to affect the bones of the head, and that it is from the vibrations which are transmitted through these bones that our perception of the direction is obtained. The three canals being situate in planes at right angles with each other are affected by the sounds transmitted through the bones of the head with different degrees of intensity, according to the direction in which the sound is transmitted; for instance, if the sound be transmitted in the plane of any one canal, the nervous matter in that canal will be more strongly acted on than that in either of the other two; or if it be transmitted in the plane intermediate between the planes of this canal and the adjacent one, the relative intensity with which those two canals will be affected will depend upon the direction of the intermediate plane. The direction suggested to the mind will correspond with the position of the canal upon which the strongest impression has been made.

There are remarkable differences in the range of the sense of hearing in different individuals, analogous to the differences in the power of vision with regard to colours. Some persons are insensible to certain sounds, which are familiar to other ears, as some are unable to see particular colours. The limits of audition in different individuals may partly depend on the condition of the auditory nerve, and partly upon the size of the membrana tympani. It is probable that animals with very large membranæ tympani can hear much graver sounds than man. The artificial tension of the membrana tympani, alluded to at a former page, is capable of inducing insensibility to sounds of a grave character, as Dr. Wollaston has shown. The ordinary range of human hearing comprised between the lowest notes of the organ, and the highest known cry of insects, includes, according to Wollaston, more than nine octaves, the whole of which are distinctly perceptible by most ears. Dr. Wollaston has, however, related some cases in which the range was much less, and limited as regards the perception of high notes; in one individual, the sense of hearing terminated at a note four octaves above the middle E of the pianoforte; this note he appeared to hear rather imperfectly, but the F above it was inaudible, although his hearing in other respects was as

:ct as that of ordinary ears; another case was that of a lady who d never hear the chirping of the field cricket; and in a third the limit was such that the chirping of the common house-row could not be heard. Dr. Wollaston supposes that inability ear the piercing squeak of a bat is not very rare, as he met with ral instances of persons not aware of such a sound.

very one must be conscious that the sensation of sound frequently longer than the exciting cause of it, as the sensation of light ι. This has been demonstrated experimentally by Savart, who d in his experiments upon toothed wheels that the removal of tooth did not produce any interruption of the sound. Other f of this is obtained from the noise which remains in the ears long travelling in a coach, or in a train upon a railroad. The ective phenomena of hearing generally result from some affec- of the brain, or of that part of it in which the auditory nerve is anted. The most common of them are tinnitus aurium, and the ing or rushing noise in the ears, which is generally indicative of ficiency rather than a redundancy of blood in the brain; or it be caused by some disturbance of local nutrition of the brain ng rise to an irregular development of nervous power.

on the subjects discussed in this chapter, the reader may consult the works of a and Sœmmering; the excellent article on the organ of Hearing by Mr. Whar-nes in the Cyclop. of Anat.; Müller's elaborate chapter on Hearing in his Phy-gy; Dr. Wollaston's paper on Sounds inaudible by certain ears, Phil. Trans., ; the article Hearing, Cyclop. Anat.; Dr. Elliotson's Physiology, where the in-us views of Mr. Wheatstone are briefly stated; and a paper by the latter phi-ber in the Journal of the Royal Institution, for July, 1827.

CHAPTER XIX.

EPHALIC NERVES EXCLUSIVELY MOTOR IN FUNCTION.—THE THIRD AIR OF NERVES.—THE FOURTH PAIR.—THE SIXTH PAIR.—THE RTIO DURA OF THE SEVENTH PAIR.—THE NINTH PAIR.

HE nerves which we shall consider in this chapter are purely or in their function; and, on this account, are conveniently ed together. We shall see, however, that from their occasional tomosis with sensitive nerves, they contain sentient filaments ch serve to inform the mind of the state of the muscles to which r motor filaments are distributed.

he *Third Pair of Nerves, or Motores Oculorum.*—These nerves connected with the crura cerebri. Each nerve emerges from the esponding crus, on the side of the locus perforatus posticus, or Tarini.

Then traced into the substance of the crus, the component fas-li of each nerve are seen to diverge from each other, and to sink

into the dark vesicular matter constituting the ***locus niger***. Here, no doubt, the filaments connect themselves with the vesicles of this mass of gray matter.

Each nerve proceeds forwards and outwards, and passes through a canal in that portion of the dura mater which forms the outer wall of the cavernous sinus into the orbit through the spheno-orbital foramen, and just as it has reached this foramen it divides into a superior and an inferior branch, the distribution of which is shown in the following table :

A. Superior division.	1. *b.* To the levator palpebræ superioris. 2. *b.* To the superior rectus oculi.
B. Inferior division.	1. *b.* To the internal rectus. 2. *b.* To the inferior rectus. 3. *b.* To the inferior oblique. 4. *b.* To the ophthalmic ganglion, also called the short root of that ganglion.

The anastomoses of the third nerve take place entirely in that stage of its course in which it lies in the outer wall of the cavernous sinus. They are with the ophthalmic division of the fifth nerve, and with the carotid branch from the inferior cervical ganglion of the sympathetic; and, as has been asserted by a few anatomists, with the sixth nerve.

Function of the Third Nerve.—Proceeding according to the method indicated at page 303, vol. i., we deduce the function of this nerve from its anatomy in man, from its anatomy in animals, from experiments, and from pathological observation.

From its anatomy in man we judge this nerve to be a motor nerve, for it is distributed entirely to muscles. These muscles are, in addition to the elevator of the upper eyelid, those upon which the principal movements of the eyeball depend; indeed, all the muscles of that organ, except the superior oblique and the external rectus. In addition to these there can be no doubt that the third nerve sends filaments to the muscular apparatus within the eye by the short root of the ophthalmic ganglion, which, after passing through that ganglion, escapes from it under the form of ciliary nerves, which may be traced to the ciliary muscle and to the iris. It is, therefore, the principal motor nerve of the eyeball, regulating all the movements of that organ, excepting those which depend on the external rectus and superior oblique muscles; and it also probably excites the movements of the iris and of the other muscular fibres within the eye. Upon this latter point, however, anatomy speaks less positively, from the fact that other nerves are distributed to the iris besides those derived from the third.

The distribution of the third nerve, in the inferior animals, leads to the same conclusion respecting its function, as that which we have deduced from human anatomy. In all the mammalia it is distributed to the same muscles of the eyeball as in man, and to the iris. In birds a similar arrangement exists, and in some species of this class we observe a remarkable development of that branch which is distributed to the iris in direct relation with the muscular activity of

that structure. In the falcons and eagles, according to Desmoulins, the third nerve is absolutely as large as in man, and this great size is due to the development of the branch which is distributed to the iris and ciliary muscle.

Experiments on this nerve are difficult of execution, and their results are therefore not free from complication; but such as have been obtained entirely confirm the view of its function which anatomy suggests. These results, as derived from the experiments of Rumbold and Fowler, of Mayo, Valentin and others, may be summed up as follows:

The application of the galvanic current to the nerve causes a convulsive contraction of the principal muscles of the globe and of the iris. The same effect is produced by mechanical irritation of the trunk of the nerve.

Section of the trunk of the third nerve in rabbits or dogs, gives rise to external strabismus with paralysis of the upper eyelid (ptosis), and dilatation and immobility of the pupil. The eyeball is given up to the influence of the external rectus and of the superior oblique muscles, the former of which, being the more powerful, determines its permanent position.

The paralysis of the iris, after section of this nerve, is so complete that the most powerful light, directed into the eye, is incapable of exciting the least contraction of the pupil. And Mayo's experiments demonstrate that the fifth nerve, which is the only other, except, perhaps, the sympathetic, connected with the iris, does not exert any motor influence upon that membrane.

When the optic nerve is irritated, the third remaining intact, and retaining its connection with the brain, the pupil contracts. This action does not take place if the third nerve have been previously cut. The motor action of the third nerve may, therefore, be excited through the optic nerve. There can be no doubt, indeed, that this is the ordinary method by which contraction of the pupil is produced during life; the stimulus of light falling upon the retina excites the optic nerve, and, through it, that portion of the brain in which the third nerve is implanted.

The effects produced by pathological changes affecting the third nerve, or that part of the brain with which it is connected, are in exact accordance with the results derived from experiment.

Paralysis of the levator palpebræ superioris muscle, permanent pointing of the eyeball in the outward direction, and a dilated, motionless pupil are the unerring signs of a paralytic lesion affecting the third nerve either at its central extremity or in some part of its course.

The third nerve may, therefore, be stated to be the nerve of motion to the elevator muscle of the upper lid, and a principal nerve of motion to the eyeball, and to the muscular apparatus within the eye. It is a nerve of great importance to vision, not only from its influence over the eyeball itself, but also from its connection with the muscular structures in the interior, on which the power of adjustment probably depends.

Of the Fourth Pair of Nerves.—These, which were called by Willis "*nervi pathetici*," are the smallest of the encephalic nerves. They are also remarkable for the very long course which they take from their origin to their point of exit from the cranium.

The origin of the fourth nerve may be referred to the mesocephale, from the superior surface of which it emerges, in close connection with the testes, or immediately behind them. Its true origin is doubtless from the olivary columns as they extend upwards beneath the quadrigeminal tubercles.

The fourth nerve emerges from the cranium through a canal in the dura mater, situate near the posterior clinoid process of the sphenoid bone, external to that in which the third nerve is lodged. It passes along the outer wall of the cavernous sinus beneath the third nerve, and in entering the orbit it rises above that nerve, and lies immediately beneath the periosteum, attaching itself to the orbital surface of the superior oblique muscle, into the posterior third of which it penetrates.

This is the only muscle which the fourth nerve supplies, and the nerve appears to be wholly lost in it. But as it passes through its canal in the dura mater, it gives off a branch, which, taking a retrograde course, passes into the tentorium cerebelli as far as the lateral sinus, where it subdivides into two or three filaments.

In its course it forms but few connections, and those apparently not constant. As it crosses the cavernous sinus it anastomoses with the sympathetic, and, as it enters the orbit, with the lachrymal.

That this nerve is the motor nerve to the superior oblique muscle anatomy does not allow us to doubt, for the muscle receives no other.

Experiments and pathological observation have thrown no satisfactory light upon its function.

In animals of great power of expression, as in apes, according to Sir C. Bell, this nerve, as well as the superior oblique muscle, is large.

Of the Sixth Pair of Nerves.—These nerves emerge from between the fibres of the anterior pyramids immediately behind the posterior margin of the Pons Varolii. It is not improbable that the true origin of each nerve is from the central part of the medulla oblongata, *the olivary columns*, and that the nerves pass between the fibres of the pyramids without forming any real connection with them.

The sixth nerve has a straight, but very short intracranial course; it penetrates the dura mater, and passes over the outside of the carotid artery, between it and the lining membrane of the cavernous sinus, entering the orbit between the two origins of the rectus externus muscle, to the ocular surface of which it is entirely distributed.

As the sixth nerve is passing along the outer side of the internal carotid artery, it forms a very celebrated anastomosis with the sympathetic, by means of two large and distinct branches, and it sometimes anastomoses with the nasal branch of the fifth.

Anatomy points to the function of this nerve as distinctly as it does to that of the fourth. The sixth nerve can have no other office

han that of regulating the movements of the abductor muscle of the ye. Experiment fully confirms this conclusion, and a few cases ave been observed in which internal strabismus was found to accompany compression of the nerve by a tumor.

Of the Facial Nerve.—(*Portio dura* of the seventh pair.)—This is ne of the most interesting and remarkable of the motor nerves. Its lose proximity to the auditory nerve led Willis to class it along with hat nerve. The former nerve is soft in its structure, and its bundles oosely coherent; the latter is more compact, and surrounded by a eurilemma of sufficient density to give to it a power of resistance ery superior to that of its neighbour.

These two nerves lie in a fossa situate on either side of the medulla blongata, and behind the posterior edge of the pons, bounded on he outside by a small lobule of the cerebellum, called *the flock* by Reil, or the lobule of the vagus or of the auditory nerve; the floor f this fossa is formed by the restiform column. The portio dura erve, which lies inside the portio mollis, penetrates the restiform olumn, and through it may be traced to the central part of the medulla oblongata, *the olivary columns*, where it connects itself with he vesicular matter.

In examining the distribution of the facial nerve, it will be found onvenient to divide it into three stages, and to enumerate its ranches in each stage.

The first stage is *intracranial*, from its origin to its exit at the nternal auditory meatus. In this stage it forms a connection with he auditory nerve by the *portio intermedia* of Wrisberg, an oblique ranch of communication, which seems like a fasciculus of fibres assing off from the portio dura, and accompanying the auditory erve into the labyrinth. This branch was described by Arnold and Goedechens as a second root of the facial nerve, but inasmuch as it loes not form a connection with the centre, distinct from that which he principal fibres of the nerve have with it, this view is not tenable. Regarding the facial as a motor nerve, this branch may possibly be viewed, as conveying motor influence to the muscular apparatus of he cochlea, which we have discovered.

The second stage is contained in the *aqueductus Fallopii*. In its assage through this canal a gangliform swelling is formed on the erve where it is joined by the Vidian which comes through the iatus Fallopii, *intumescentia genuformis*. A question arises as to he nature of this swelling; is it a ganglion, or, is it merely the result f the separation of the fibres of the nerve at this situation? We ave failed to satisfy ourselves by microscopic examination of the xistence of vesicular matter in it, but we have found a large numer of gelatinous fibres in it, as well as of tubular fibres.*

At this swelling the facial forms a communication by means of the *reater superficial petrosal nerve* with Meckel's ganglion, and by the *esser superficial petrosal nerve*, with the otic ganglion; a third branch

* Morgagni has lately published an elaborate paper, in which he maintains the anglionic character of this swelling.—*Annali Univ. di Medicina*, 1845.

less constant than these two, is distributed to vessels and dura mater on the surface of the petrous bone. As it lies in the aqueduct of Fallopius, the facial nerve gives off the following branches. 1. A branch to the membrane of the fenestra ovalis. 2. A twig to the stapedius muscle. 3. The chorda tympani. 4. An anastomotic twig with the auricular branch of the vagus nerve.

The third stage commences at the stylomastoid foramen; here the nerve passes obliquely through the parotid gland, in the substance of which it divides into its terminal branches. Immediately on its emergence from the stylomastoid foramen, it gives off: 1. The *posterior auricular*, or *auriculo-occipital*, distributed to the small muscles of the ear, and the occipital muscle. 2. The *stylohyoid* branch to the stylohyoid muscle. 3. The *submastoid* branch to the digastric muscle. And lastly, it divides into two branches, the *cervico-facial*, distributed to the platysma, and to the muscles of the lower lip and chin, and the *temporo-facial*, which is distributed to the orbicular muscle of the eyelids, the corrugator supercilii, and the muscles of the nose and upper lip. The plexiform distribution of these nerves on the face forms the well-known *pes anserinus*. The facial nerve anastomoses freely with the superficial temporal, frontal, infra-orbital, buccal and mental branches of the fifth pair, and with branches of the cervical plexus.

Function of the Facial Nerve.—Referring to the anatomy of this nerve, we find it distributed by the vast majority of its fibres to muscles, and those minute branches, respecting the ultimate destination of which some doubt exists, may be, and probably are, distributed to muscular fibres. The muscles which are supplied by the facial nerve are chiefly those upon which the aspect of the countenance and the balance of the features depend. The power of closing the eyelids depends on this nerve, as it alone supplies the orbicularis palpebrarum; and likewise that of frowning, from its influence upon the corrugator supercilii. Anatomy indicates, therefore, that this nerve is the motor nerve of the superficial muscles of the face and ear, and of the deep-seated muscular fibres within the ear.

This conclusion is abundantly confirmed by comparative anatomy. For wherever the superficial muscles of the face are well developed, and the play of the features is active, this nerve is large. In monkeys it is especially so. That extremely mobile instrument, the elephant's trunk, is provided with a large branch of the facial as its motor nerve. In birds, on the other hand, it is very small, being limited to the stylohyoid branch.

Section of the nerve, at its emergence from the stylomastoid foramen, has been followed by paralysis of the muscles of the face, and of the orbicularis palpebrarum, in the hands of all experimenters. Formerly when this nerve was supposed to preside over the sensibility of the face, it was thought to be the seat of tic douloureux, and was upon several occasions cut. But this operation yielded no relief to the sufferings of the patient, and only served to illustrate the function of the nerve, since it was always succeeded by paralysis of

: on that side, total loss of control over the features, of the f frowning, and of closing the eyelids.

diseased states of the facial nerve illustrate its physiology in t interesting manner. It may be paralyzed from the influence benumbing its superficial fibres, or from the compression of r at the angle of the jaw, or from a carious state of the petrous of the temporal bone. From whatever cause the paralytic ses, the effect is invariably the same; the patient is unable to s eyelids, and in some rare cases he has not the power even ximating them to each other in the least degree. He cannot e ala nasi or either lip on the affected side, and if told to the mouth, as in whistling, he is unable to do it. When hs, the movement is all on one side, and the angle of the m the sound side is drawn upwards towards the ear, whilst the paralyzed side hangs below its ordinary level. With so aralysis of the superficial muscles, the deeper seated ones lirect the masticatory movements of the lower jaw, and are l by the fifth nerve, remain unaffected, and the sensibility of is unimpaired.

the paralytic affection of this nerve has been of long stand-re is great wasting of the muscles on that side of the face, a the buccinator, which is supplied by the fifth nerve also, o such an extent that it becomes reduced to a mere inert ne, and flaps to and fro as the patient speaks, interfering to a gree with the clearness of his articulation.

the facial nerve in some degree influences the movements of palate, has been suggested by the record of cases in which the muscles on one side of the face has been accompanied lysis of the corresponding half of the velum. That this a sometimes accompanies the other signs of this form of annot be doubted; but the frequency of its absence is suffi-denote the trifling influence of the nerve upon the palatine . Valentin irritated the greater superficial petrosal nerve, the probable source of any nervous filaments from the facial nuscles of the palate, but failed to excite any movement of uscles in fifteen experiments.

uncertainty exists likewise as regards the function of the tympani. Regarding it, as we do, as a branch of the portio e think it must exercise a motor influence upon the parts to t is distributed, of which the principal is the duct of the sub-y gland. But the curious relation which it bears to the mal-d incus denotes that it may have something to do with the ism of the organ of hearing.

s been made a question, how far the facial nerve possesses sibility, and from whence it derives sensitive fibres. That of it causes pain, has been sufficiently proved by various enters, and it appears that the sensibility is more marked nerve has passed through the parotid gland. The sources ensitive fibres appear to be clearly indicated by the various oses which the facial nerve forms in its several stages—in

the Fallopian aqueduct with the vagus nerve, in the face with the fifth nerve, and in the neck with spinal nerves; the communications with the fifth nerve being very numerous. There are, therefore, sufficient means of communication with sensitive nerves to explain the sensibility of the facial without its being necessary to have recourse to the theory of Arnold, and to rank it with the double-rooted nerves.

Of the Ninth or Hypoglossal Nerve.—The origin of this nerve is from the side of the medulla oblongata along the anterior margin of the olivary body. Ten or twelve fasciculi of fibres emerge here from the central part of the medulla oblongata, and unite into two bundles, which coalesce and emerge as one nerve through the anterior condyloid foramen.

The ninth nerve, on escaping from the anterior condyloid foramen, passes outwards, and winds forwards around the pharynx, to the deep surface of the tongue, being closely related to the internal carotid artery, and the jugular vein, and winding round the external carotid, in its course to the upper and anterior part of the neck.

Immediately after its emergence it forms anastomoses with the vagus nerve, the superior cervical ganglion, and with the cervical plexus, and then it gives off, 1. The descending branch, which forms remarkable anastomotic arches with branches of the second and third cervical nerves, either within or in front of the sheath of the common carotid artery and jugular vein. From the convexity of this arch or these arches, there pass branches to the sterno-hyoid, and sterno-thyroid muscles, and to the anterior belly of the omo-hyoid. 2. It gives nerves to the thyro-hyoid, genio-hyoid, hyoglossus, and styloglossus muscles. 3. On the inferior surface of the tongue it breaks up into its terminal or glossal branches which pass into the muscular structure of the tongue.

As the hypoglossal nerve crosses the hyoglossus muscle it forms an anastomosis with the lingual branch of the fifth pair.

Function of the Ninth Nerve.—As this nerve has no other connection than with muscles we cannot regard it in any other light than as a motor nerve. The muscles to which it is distributed are those of the tongue, and as this is the principal nerve to these muscles, we may justly regard it as the motor nerve of the tongue. The other nerves of the tongue, the lingual branch of the fifth and the glosso-pharyngeal, are obviously traceable to the mucous membrane.

In the lower mammalia the ninth nerve is distributed precisely as in man, and it is proportional in size to the muscular activity of the tongue.

Numerous experiments have been made on this nerve. Section of it on one side paralyzes the motor power of the tongue on that side. And galvanic irritation of it throws the muscles on the same side into convulsive action.

Several instances have been observed of tumours compressing this nerve, and causing paralysis of the muscles of the tongue on the same side. The tongue participates in the hemiplegic paralysis which results from an apoplectic clot in the brain, or other extensive disease of that organ, along with all those parts whose nerves are

planted in some part of the extended centre of volition, and are linarily excited by a mental stimulus. In such cases the loss of wer in the tongue is usually indicated by its deviation to the ralyzed side in its protrusion, though occasionally the tip is turned wards the sound side.

We may then conclude from human and comparative anatomy, m experiment and pathological states, that the ninth nerve is the tor nerve of the tongue. Its anastomoses with the vagus, and th the fifth, make it probable that it contains some sensitive filaents, and this is confirmed by experiments which show that some sibility is possessed by the nerve, and that this is greatest the arer we approach the tongue. But that it has no influence upon te or upon the common sensibility of the organ, is proved by the impaired state of both those powers, after complete section of the rve.

a addition to the principal systematic works on physiology, reference may be de to Valentin, de Functionibus Nerv. Cerebr.; the Papers of Sir C. Bell, colsd in an octavo volume, 1844; Mayo's papers in his Anat. and Physiol. Comataries, and his Physiology; Longet sur le Système Nerveux.

CHAPTER XX.

THE COMPOUND ENCEPHALIC NERVES. THE FIFTH PAIR. THE EIGHTH PAIR.

It is proposed to devote this chapter to the examination of the ysiological history of those encephalic nerves which, from their apound nature, combine the functions of sensitive and motor ves. These are the fifth pair and the eighth pair.

The fifth pair of nerves is one of the most interesting and extenely connected nerves in the body. It presents a remarkable reablance to spinal nerves in its mode of origin, a fact which bears ngly on the determination of its functions. The first point of emblance is that its origin is by two roots, one large, and the er small; and secondly, its larger root is involved in a ganglion, two roots being quite distinct until after the formation of the ganon, when the lesser one coalesces with one of the nerves which ings from the ganglion, to form the inferior maxillary nerve.

The two roots are implanted in the same column of the medulla ongata. They remain, however, quite distinct in the substance of medulla. Penetrating the latter at the crus cerebelli, between transverse fibres of the pons, each root may be traced through a arate but nearly parallel course downwards to the olivary column, ere each forms its separate connection with the vesicular matter.

The ganglion (*ganglion Gasserii*) which is formed upon the larger

root of the fifth nerve is situate in the middle fossa of the cranium upon the upper surface of the petrous bone, and the middle lacerated foramen, and behind the great ala of the sphenoid. It is of a triangular form, its base curvilinear and directed forwards and outwards. From this base there proceed three nerves, the ophthalmic on the inside, the superior maxillary in the middle, and the inferior maxillary on the outside. Of these the first two consist exclusively of fibres derived from the larger root and ganglion; the third, the inferior maxillary, is composed of fibres derived from both roots. This, therefore, is the only portion of the fifth nerve which is strictly compound, and it constitutes the largest portion of the nerve.

The distribution of the nerve may be understood by reference to the subjoined tabular arrangement of the distribution of each of its three divisions.

TABULAR VIEW OF THE DISTRIBUTION OF THE FIFTH NERVE.

I. Ophthalmic—(anastomoses with sympathetic).

a. Lachrymal
- 1. *b.* To lachrymal gland.
- 2. *b.* To unite with temporo-malar branch of supra-maxillary nerve.
- 3. *b.* To external canthus, eyelids, &c.

b. Frontal .
- 1. Supra-trochleator *b*, to integuments of internal canthus, conjunctiva, lids, &c.
- 2. Continued frontal nerve, or supra-orbital.

c. Nasal .
- 1. Lenticular *b*, to the ophthalmic ganglion.
- 2. Ciliary nerves,—two in number.
- 3. Nasal *b*, to the mucous membrane and skin of the anterior part of the nostril.
- 4. Infra-trochleator, to the inner canthus and side of the nose.

II. Superior Maxillary—(three stages, cranial, spheno-maxillary, orbital).

a. Temporo-malar *b*.—Anastomoses with the lachrymal, and is distributed to the integument of the temporal and malar region.

b. Spheno-palatine *b*.—Two or three in number, which pass to the spheno-palatine ganglion.

c. Post, superior dental *b*.—Two or three in number, going to the posterior teeth of the upper jaw; one branch passing along the interior of the antrum, and anastomosing with the anterior superior dental.

d. Ant. superior dental *b*.—Supplies the anterior teeth of the upper jaw.

e. Facial . . . 1. Palpebral, 2. Labial, 3. Nasal — Supplying the integuments of those regions.

III. Inferior Maxillary.

a. Masseteric *b*.—To the masseter muscle.

b. Deep temporal *b*.—Two in number, to the temporal muscle.

c. Buccal *b*.—Anastomoses with branches of the facial, and goes to the external pterygoid and buccinator muscles, and to the mucous membrane of the mouth.

d. Pterygoid *b*.—To the circumflexus palati and internal pterygoid muscle.

e. Superficial temporal *b*.—Anastomoses with the facial, and is distributed to the skin of the temporal region and external ear.

f. Inferior dental *b*.
- By its mylohyoid branch to the mylohyoid and digastric muscles.
- To the teeth, alveoli and gums of the lower jaw;
- and by the mental branch to the integuments and mucous membrane of the lower lip.

g. Lingual *b*. .
- Is joined by the chorda tympani.
- Connecting filaments to the submaxillary ganglion or plexus.
- Anastomotic branches to the ninth nerve.
- Branches to mucous membrane of the tongue.

Function of the fifth nerve.—The determination of the functions of the roots of spinal nerves has afforded the clue to that of the functions of the roots of the fifth nerve. The analogy of the smaller root of the fifth with the anterior spinal root, and of the larger one with the posterior spinal root has long been admitted by anatomists.—Hence an analogy of function must be admitted, and the former must be viewed as consisting of motor fibres, the latter of sensitive ones; and by tracing each of the three great divisions of the nerve, we may determine its function by its constitution, according as it derives its fibres from either root or from both. The ophthalmic and superior maxillary are composed of fibres derived exclusively from the larger root; they are, therefore, sensitive nerves. The inferior maxillary consists of fibres derived from both roots, and consequently is both motor and sensitive. Sir C. Bell, in his original exposition of the functions of this nerve, fell into error from having neglected to avail himself of this method of analyzing the constitution of each of its three divisions from which he would have seen that it is the inferior maxillary alone which derives its fibres from both roots, and which perfectly resembles a spinal nerve in constitution.

The distribution of the three divisions of the fifth nerve confirms most amply the view of its physiology suggested by the anatomy of its origin. The ophthalmic and superior maxillary are distributed entirely to sentient surfaces, or anastomose with motor nerves (the facial). They supply the skin of the forehead, of the eyelids, the conjunctiva, the eyeball, the mucous membrane of the nostrils, the integuments of the face, the upper lip, the nose, the beard on the upper lip, the integument of the ear, the temple, and the whiskers; they are the sensitive nerves to these regions. The inferior maxillary has two distinct sets of branches, the one by which the muscles of mastication are supplied—the other, which go to the integuments of the lower lip and chin, and the beard, and the mucous membrane of the mouth and tongue. This nerve is, therefore, the nerve of mastication, and of sensation to the surfaces above named.

Repeated experiments in the hands of various physiologists, none of which, however, were more conclusive than those of Mayo, indicate the same views of function. Division of the ophthalmic or of the superior maxillary induced loss of sensibility without muscular paralysis, leaving only such an impairment of the motor power as destruction of the sensitive nerves invariably produces, by impairing the power of exact adjustment, for which a high degree of sensibility is necessary. But when the inferior maxillary nerve was cut, then both the power of mastication was destroyed on the same side, and the sensibility of the lower part of the face and tongue was lost. If the nerve were divided in the cranium, the whole side of the face and forehead, with the eyeball and nose, became insensible, and the muscles of mastication were paralyzed. Irritants might then be applied to the eyeball, without exciting winking, or causing pain, and strong stimulants might be introduced into the nostrils without creating the least irritation. When the trunk of the nerve within the cranium of an ass was irritated, the jaws closed with a snap from the excita-

tion of the motor fibres, which are distributed to the muscles of mastication.

The conclusions which we draw from anatomy and from experiment are confirmed by the histories of cases in which the fifth nerve had been diseased. In such instances we may observe the most marked separation of the motor and sensitive power, when the larger portion only or the two superior divisions of the nerve are affected, and we find both motion and sensation destroyed when the whole trunk of the nerve is involved in the disease. It is not uncommon in such cases to find the eyeball totally insensible to every kind of stimulus, the nose quite unexcitable by the fumes of ammonia, or the most pungent vapors, and the mucous membrane of the mouth so insensible to the contact of foreign matters that a morsel of food will sometimes remain between the gum and the cheek until it has become decomposed. The insensibility of the eyeball exposes it to the permanent contact of irritating particles of dust, &c., which excite destructive inflammation of its textures. The whiskers may be pulled forcibly without sensation. The muscles of mastication become wasted and inert, as shown by the distinct depression in the regions of the masseter and temporal muscles, but the superficial muscles, on which the play of the features depends, preserve their natural condition.

The fifth nerve may, therefore, be regarded as the motor nerve in mastication, and the sensitive nerve to that great surface, both internal and external, which belongs to the face and anterior part of the cranium. From its great size, and the large portion of the medulla oblongata with which it is connected, it may excite other nerves which are implanted in that centre near to it. Thus it may be an excitor to the portio dura, as in winking—or to the respiratory nerves, as in dashing cold water in the face, or in sneezing. Its lingual portion distributed to the mucous membrane of the tongue is at once a nerve of taste, touch, and common sensibility, and its connection with the papillary structure of the red parts of the lips constitutes it a pre-eminently sensitive nerve of touch in those regions.

The study of the pathological conditions of this nerve illustrates its physiology in a highly interesting manner. In the dentition of children, whether primary or secondary, it is always affected, more or less: and in excitable states of the nervous centres, the irritation of it consequent upon the pressure of the teeth often gives rise to convulsions, the brain and spinal cord being irritated; and we can often trace to such irritation, whether in infancy or in childhood, the foundation of epileptic seizures in subsequent years. Painful affections of the face (*neuralgia*) have their seat in this nerve; *tic-douloureux*, for example. Many of the instances of painful affection of this nerve or of branches of it, which come under our observation, are well marked examples of reflected sensation, the primary irritation being conveyed to the centre by the vagus or the sympathetic from the stomach or intestinal canal. No one of these is so common as the pain over the brow, which so often follows derangement of stomach digestion; and which may frequently be instantaneously

by taking away the source of irritation, as by neutralizing
l in the stomach. Frequently also the branches of this
greater or less number, on one or both sides, may, accord-
ie humoral view, form a focus of attraction for a morbific
enerated in the blood, in persons exposed to the paludal
r in persons of rheumatic or gouty constitution; in these
in most others of similar pathology, the neuralgia occurs in
is of greater or less severity, each paroxysm being followed
od of convalescence, which lasts, it may be supposed, until
id matter has been again accumulated in quantity sufficient
a high degree of irritation of the nerves.

Eighth Pair of Nerves.—We must examine separately the
and physiology of each of the three nerves, which, taken
constitute the eighth pair; and, first,

Glossopharyngeal.—This nerve consists of several small
of fibres, which lie close together, and are implanted in the
rt of the medulla oblongata behind the olivary body. The
netrate to the centre of the medulla (the olivary columns),
ey connect themselves with a special accumulation of vesi-
tter.

lossopharyngeal nerve escapes through a small foramen in the
ter, at the anterior part of the foramen lacerum posterius.
tely after it has passed this foramen, a small ganglion, which
only some of the fibres of the nerve, is formed upon it. This
nglion jugulare, discovered by Ehrenritter. Beyond this,
ed in a fossa in the side of the jugular foramen, is another
which involves all the fibres of the nerve; this is the *gan-
rosum*, originally described by Andersch. After its escape
the jugular foramen, the glossopharyngeal descends by the side
harynx, between the styloglossus and stylopharyngeus mus-
l in the region of the tonsil breaks up into its terminal
l.

the ganglion of Andersch, a nerve passes off, and enters the
the tympanum, occupying a groove upon the surface of the
ry beneath the lining membrane of the tympanum. This
lately called the branch of Jacobson, although described by
h and Winslow, divides into six filaments, which form the
plexus or anastomosis. These filaments are as follows:—
ie membrane of the fenestra ovalis. 2. To that of the fenes-
da. 3. To the carotid plexus in the carotid canal. 4. To
us membrane of the Eustachian tube. 5. An anastomotic
which, passing through the upper wall of the tympanum, unites
greater superficial petrosal nerve. 6. An anastomotic branch
tic ganglion called by Arnold the *lesser superficial petrosal*

he petrosal ganglion the glossopharyngeal nerve forms anas-
with the facial and the par vagum.

ollowing are the terminal branches of the glossopharyngeal
1. A branch to the digastric and stylopharyngeal muscles.
e or four carotid filaments which descend along the internal

carotid artery, and may be traced as far as the bifurcation of the common carotid. These nerves anastomose with others from the superior cervical ganglion, and form a plexus round the carotid artery. 3. Tonsillitic branches, which are numerous, and along with nerves from the vagus and from the superior cervical ganglion of the sympathetic, form a plexus beneath the mucous membrane in the vicinity of the tonsil, which is called the *pharyngeal* or *tonsillitic* plexus. Some of the branches of this plexus are distinctly connected with the mucous membrane, others with the muscular fibres of the pharynx. 4. Pharyngeal branches, which are distributed to the mucous membrane of the wall of the pharynx. 5. Lingual branches; these are given to the mucous membrane at the base and side of the tongue, and one may usually be traced into the soft palate.

From the preceding statement it appears that the distribution of the glossopharyngeal nerve is chiefly, if not exclusively, to sentient surfaces. Even its tympanic branch is connected with the lining membrane of that cavity and of the Eustachian tube. But its principal branches are those on the pharynx and tongue, which latter region, however, it must not be forgotten, has another nerve distributed to its mucous membrane. Its digastric branch seems to be anastomotic with a similar one from the facial.

The mode of origin of this nerve affords but a feeble clue to the discovery of its physiological import. Müller and others attach some value to the existence of the ganglion, involving only some of its fibres shortly after their origin, and from the analogy with spinal nerves and with the fifth, they infer that the glossopharyngeal must be a compound nerve of double origin, containing both motor and sensitive fibres. There is not, however, sufficiently certain evidence of the existence of two roots to this nerve to justify us in founding upon it an argument respecting its function.

The most extensive series of experiments on this subject are those of Dr. John Reid, and they have very satisfactorily developed the proper functions of the nerve.

Section of the nerve, or irritation of it, always caused pain, and hence it may be said to contain fibres of common sensation.

When the trunk of the nerve was irritated before giving off its pharyngeal branches, extensive muscular movements of the throat and lower part of the face were produced. It was found that these movements were equally produced, and to as great an extent, if the nerve had been cut a short way below its exit from the cranium, and the cranial end of it irritated. Hence it was evident that the movements were caused, not by the direct influence of the branches of the glossopharyngeal upon the muscles, but by that of the cranial end of the nerve upon the medulla oblongata, whence the change was propagated to the muscles through the fibres of the vagus nerve and through those of the facial, which emanate from the same part of the nervous centre.

This view of the mode in which the glossopharyngeal causes muscular action is confirmed by the result of experiments on it in animals just dead. When the nerve was irritated under those circumstances,

no movements could be excited, provided it was sufficiently insulated from the pharyngeal branches of the vagus. Now, were the fibres of the glossopharyngeal motor, there is no doubt that mechanical irritation of them would have caused muscular contraction.

Hence, the glossopharyngeal is one of those sensitive nerves which is capable of exciting motion through its influence upon motor fibres implanted immediately contiguous to it in the nervous centre.

It appeared, however, that other fibres were capable of exciting the movements of the pharynx, for when the trunk of the nerve was cut on both sides, the movements of deglutition continued.

Dr. Reid's experiments showed that section of the lingual branches of this nerve did not destroy the power of taste, and therefore that the glossopharyngeal cannot be regarded, according to the views of Panizza, as the sole nerve of that sense. And this accords so completely with anatomy, which shows that a part of the tongue, enjoying the gustatory power, is supplied by the fifth nerve and that only, and that another part, also enjoying the same power, is supplied only by the glossopharyngeal, that no doubt can be entertained of the correctness of the view which assigns gustatory power to this nerve as well as to certain filaments of the fifth pair. At a former page we have referred to a case of paralysis of the fifth nerve in which, while taste was altogether lost in the anterior part of the tongue, it continued at its posterior part; the fifth nerve which supplies the tongue in the former situation being paralyzed, whilst the glossopharyngeal, distributed in the latter region, was free from disease. Two very interesting cases confirmatory of the same view have since been published by Mr. Dixon, in the *Med. Chir. Trans.*, vol. xxviii.

Disease, limited to this nerve, is of extremely rare occurrence. In one instance that we have met with, in which its neurilemma was considerably thickened, there was not only total inability to swallow, but likewise the mucous membrane of the pharynx was quite insensible to stimuli, and that surface of the fauces which, in health, may be excited by the slightest touch of a feather, admitted even of friction without any uneasiness to the patient, or the least muscular contraction.

The functions of the glossopharyngeal nerve are highly worthy of an attentive study, in reference to the very important question discussed at a former page, as to the existence of distinct spinal and cerebral fibres. We have in it an example of a nerve at once excitor and sensitive; it is a most marked instance of a nerve, not motor in itself, but capable of exciting motion by its influence on others. Yet no part of the surface to which it is distributed can be touched without sensation being excited, and with it motion. The stimulation even of that portion of the tongue which receives filaments from it, is capable of exciting the pharyngeal muscles to contract, although the action is not so energetic as when the stimulus is applied to the isthmus faucium. In examining the fauces of patients, the practitioner has frequent opportunity of observing the extraordinary sensibility of the mucous membrane, where the glossopharyngeal nerve ramifies, and

the remarkable rapidity with which the pharyngeal muscles respond to the slightest stimulus applied to it.

The following conclusions may be adopted respecting the glosso-pharyngeal nerve.

1. It is the sensitive nerve of the mucous membrane of the fauces and of the root of the tongue, and in the latter situation it ministers to taste and touch as well as to common sensibility; and being the sensitive nerve of the fauces, it is probably concerned in the feeling of nausea which may be so readily excited by stimulating the mucous membrane of this region.

2. Such are its peripheral organization and central connections, that stimulation of any part of the mucous membrane in which it ramifies, excites instantly to contraction all the faucial muscles supplied by the vagus and the facial nerves, and the permanent irritation of its peripheral ramifications, as in cases of sore throat, will affect other muscles supplied by the facial nerve likewise. It is, therefore, an excitor of the movements necessary to pharyngeal deglutition.

Of the Vagus Nerve.—The *par vagum* or *pneumogastric nerve* is of all the encephalic nerves the most extensively connected.

This nerve emerges from the medulla oblongata immediately below the glossopharyngeal, by from eight to ten fasciculi of fibres which pass outwards to an opening in the dura mater, through which it escapes in company with the spinal accessory. The line along which its fascicles emerge from the medulla is placed a little behind the posterior edge of the olivary body. These fascicles penetrate the olivary columns, and are there implanted in especial accumulation of vesicular matter.

A ganglion is formed upon the vagus nerve immediately it enters the canal of the dura mater. From this ganglion some small nerves come off. Shortly after the emergence of the vagus nerve from the base of the skull, another gangliform enlargement is formed upon it, which Arnold calls *plexus gangliformis*. It is at the situation of this enlargement that the union between this nerve and the internal branch of the spinal accessory takes place.

At its upper part the vagus forms numerous anastomoses, at first by nerves given off from the ganglion. These are, *a*, with the ganglion petrosum of the glossopharyngeal, *b*, with the carotid branch of the superior cervical ganglion, *c*, with the facial nerve, through the branch called by Arnold *the auricular*, which is situate in the jugular fossa outside the vein, and is seen through its coats when that vessel is laid open. It anastomoses likewise with the ninth nerve, with the cervical plexus, and with the superior cervical ganglion, in a manner sometimes very intimate.

The following branches are given off by the vagus nerve.

1. *The Pharyngeal Branch.*—This is believed by some anatomists to be derived altogether from the spinal accessory nerve, through its anastomosis with the vagus. It forms, along with the glossopharyngeal, some cervical nerves and sympathetic filaments, the pharyngeal plexus, and its branches seem to be distributed to the muscles of the

:. Sometimes there are two pharyngeal branches, a superior
:rior.

he Superior Laryngeal Nerve, which gives off the external
il nerve to the crico-thyroid muscle, and is itself distributed to
:ous membrane of the larynx, and sends an anastomotic branch
iferior laryngeal nerve.

:rvical Cardiac Branches.—These are at least two in number
side, and they pass down in front of the innominata on the right
the aortic arch on the left, and contribute to form the small
between the aorta and pulmonary artery.

he Inferior Laryngeal Nerve.—This important nerve is distri-
all the intrinsic muscles of the larynx, except the crico-thyroid.
:uliarity of its course has given it the name *recurrent*. It has
ing relations differing on the right and left side. Arising on
side just in front of the arch of the aorta, it winds round the
ty of that vessel, and ascends between the œsophagus and the
to the lower edge of the inferior constrictor of the pharynx.
rve of the right side separates from the trunk just above the
ian artery, and winds round it, ascending in the neck to a
destination.

recurrent nerves before their ultimate distribution give off
s to the heart, to the trachea, to the œsophagus, and to the
constrictor of the pharynx.

ferior or Thoracic Cardiac Branches, distributed to the peri-
i, and the cardiac plexus.

nterior Pulmonary Branches, passing in front of the bronchial
the root of the lung, and penetrating the pulmonary substance,
ith the ramifications of the bronchus, and of the pulmonary

Esophageal Branches, which are very numerous, and distributed
:sophagus, throughout its entire length.

racheal Branches, to the mucous membrane and muscular fibres
achea.

osterior Pulmonary Branches; these go to form the posterior
ary plexus, of which there are a right and a left plexus,
nastomose freely with each other, situate behind the bifurca-
the trachea. The ramifications of this plexus follow chiefly
:se of the bronchial tubes, being distributed to their mucous
ne and muscular fibres.

giving off the pulmonary branches, the vagi nerves pass
long the œsophagus, giving off branches to it, and passing
the œsophageal opening of the diaphragm, are distributed to
iach. The *left* nerve passes in front of the cardiac orifice,
ome filaments over the splenic *cul-de-sac*, and follows the
of the lesser curvature; some of its branches passing in the
mentum to the liver, whilst the rest are distributed to the
the stomach. The *right* nerve passes behind the cardiac
and after giving several branches to the stomach, sinks into
r plexus.

outline of the anatomical distribution of this extensively con-

nected nerve is sufficient to show that it is devoted to muscular fibres as well as to sentient surfaces, and that it must be regarded as a compound nerve, sensitive as well as motor. The existence of the ganglion, which involves all the fibres of the vagus nerve, in the canal of the dura mater, has led to the opinion that all its proper fibres are sensitive, while those branches which go to muscles are derived from its large anastomosis with the spinal accessory. Whether this view be correct or not, it is certain that a free communication exists just below the basis cranii between the vagus and the spinal accessory nerves.

The branches of this nerve, which anatomy shows to be purely motor, are the pharyngeal and the inferior laryngeal, whilst the cardiac, œsophageal, pulmonary, and gastric branches are doubtless of a mixed character, and the superior laryngeal is purely sensitive, with the exception of those of its fibres which form the external laryngeal nerve.

The distribution of the vagus nerve in the inferior mammalia corresponds very closely with that in man, and so far confirms the views of function suggested by human anatomy. Its connection with the sympathetic in some of the mammalia (the dog and cat, for instance), is more intimate than in man, for the upper part of the cervical portion of the sympathetic is closely connected with it, so that they appear to form but one nervous trunk. The general disposition of the nerve in birds and reptiles does not materially differ from that in man, and it has an analogous arrangement in fishes.

The results of the numerous experiments of which this nerve has been made the subject, accord in a striking manner with the conclusions deducible from anatomy. Thus, mechanical and galvanic irritation of the pharyngeal branches has always produced contractions of the pharynx: irritation of the superior laryngeal nerve causes contraction of the crico-thyroid muscle only, whilst that of the inferior laryngeal causes forcible contraction of the laryngeal muscles as well as of the inferior constrictor of the pharynx. In a living animal the slightest touch to the mucous membrane of the glottis will cause the instant closure of that fissure, if the superior laryngeal nerve be uninjured, but if that nerve be divided on both sides, the glottis may be irritated with impunity. It is plain, then, that the inferior laryngeal is the principal motor nerve of the larynx, and that the superior laryngeal is at once the sensitive nerve, and the excitor of the motor action of the inferior laryngeal through the medulla oblongata.

It is scarcely necessary to remark how untenable is the opinion advocated by Majendie, that an antagonism exsits between the superior and inferior laryngeal nerves, the one acting upon the constrictors, the other upon the dilators of the larynx. The superior laryngeal nerve supplies, as we have seen, only one muscle, and the inferior, to which he assigns the office of opening the glottis, supplies those muscles which are the principal agents in closing it.

Impairment or destruction of vocal power is a constant accompaniment to injury or complete section of the recurrent nerve.

An interesting experiment of Dr. J. Reid illustrates the power of each laryngeal nerve respectively. When the inferior laryngeals were cut, the superior remaining intact, a probe introduced into the glottis occasioned signs of pain and efforts to cough, without any contraction of the glottis. But when the superior laryngeal nerves were cut, the recurrents being unimpaired, the probe could be introduced without exciting any irritation or effort whatever.

This experiment demonstrates unequivocally, that the spasmodic action induced in the larynx by the application of a stimulus to its mucous membrane, must be referred to the class of physical nervous actions, and results from the influence of the superior laryngeal upon the inferior, through the connection of their respective points of implantation in the nervous centre.

There can be no doubt that the motions of the œsophagus are regulated by the various œsophageal fibres given off from this nerve, in its course through the thorax. Irritation of its trunk has always produced contractions of the œsophagus, as testified by many experimenters. These contractions, Dr. Reid states, extended throughout the whole tube to the cardia, where they became slow and vermicular; the œsophagus being shortened and diminished in calibre at each application of the irritant.

Distinct palsy of the œsophagus may be produced by section of the vagus in the neck. The following effects followed this experiment by Dr. Reid on a rabbit, which had been kept fasting for sixteen hours previous to the experiment. The animal ate a quantity of parsley, had considerable dyspnœa and cough, with many efforts to vomit. It died in five hours. The œsophagus was found full of parsley throughout its entire extent down to the stomach, *which was also filled*, although not distended; and a good deal of the parsley had passed into the trachea and bronchial tubes, and even into the minute air-cells of the lungs.

The appearances in this experiment indicated complete paralysis of the œsophagus. This tube was filled by the propulsive power of the pharynx, which sent on morsel after morsel, until the whole stomach and gullet were filled, the latter being perfectly passive; and after these parts were occupied, and thus resisted the further passage of the parsley, it found its way more readily into the larynx and trachea.

It may be inferred from this and similar experiments that something more than an irritable condition of the muscular coat of the œsophagus is requisite in order to insure its contraction when distended by food.

The muscular fibres were quite uninjured, and, therefore, ought to have acted, if the stimulus of distension were alone sufficient to excite their contraction. The true cause of their inaction was the destruction of the nervous circle through which the sensitive nerves of the œsophagus could excite its motor nerves. This portion of the act of deglutition, therefore, is like that in the pharynx, a physical action, brought about by the impression of the food upon the sentient nerves of the œsophagus, which propagate their change to the centre

where the motor fibres become excited. It cannot be said, however, that the mind is unconscious of this part of the act of deglutition, although it may be reasonably admitted that it has no necessary share in it.

The results of section of the cardiac nerves show that these nerves exert only a partial influence upon the heart: the destruction of them affects the actions of that organ only to a limited degree, inasmuch as the heart receives nerves from the sympathetic as well as from the vagus.

Numerous experiments demonstrate most unequivocally that this nerve is of vast importance to the function of respiration. Section of one nerve produces no effect upon the respiratory organs, either structural or functional. Dr. Reid made careful examinations to ascertain if, after cutting out a large portion of one nerve, the lung of that side suffered any alteration in its texture, but he could not detect any. But when both nerves have been divided above the giving off of the pulmonary branches, the most severe dyspnœa comes on, the respirations are generally much diminished in number, the animal breathes just like an asthmatic; after a short time the lungs become congested and œdematous, and the bronchial tubes filled with a frothy serous fluid. When a piece has been cut out of each nerve, or the cut ends of the nerves are kept apart, the animals never survive beyond three days, and during the whole of that period they suffer severe dyspnœa. If the cut ends of the nerves be kept in contact, the animals will live ten or twelve days.

It may be inferred from Dr. Reid's experiments, that section of the vagi nerves does not destroy that peculiar feeling of distress (*besoin de respirer*), which is occasioned by the want of fresh air in the lungs. He proved that animals, in which the vagi nerves had been cut, struggled violently, and seemed to suffer greatly, when the access of air to the lungs was cut off by compressing the trachea.

In such cases as that just described, the only channel through which sensitive impressions could be conveyed from the lungs to the brain, is the sympathetic system, and it is to the afferent power of the sympathetic nerves, and possibly to the same power in the cutaneous ramifications of the fifth and of the spinal nerves, that we must attribute the imperfect excitation of the respiratory act, which, under these circumstances, takes place.

The phenomena which follow section of both vagi are doubtless to be explained by the imperfect manner in which the centre of respiration is excited, after the destruction of the influence of these nerves consequent on their section. The movements, after the section, are partly of the voluntary kind, produced by the sense of distress occasioned by the imperfect supply. The asthmatic state which also follows the section, may perhaps be in part caused by the irritation of the central portion of the nerve, exciting the medulla oblongata and the extremities of the motor nerves of respiration.

Lastly, the office of the gastric branches of the vagi nerves, appears from Reid's experiments to be chiefly to control the move-

nents of the muscular coat of the stomach. Mechanical irritation of these nerves causes slow and vermicular contractions of this tunic. Section of them may cause, in the first instance, vomiting and loathing of food, and it may retard the digestive process, but it does not put an end to it. For not only do animals, with the vagi cut, eat food from day to day, but, if killed at a sufficient period after digestion, their lacteals are found filled with chyle; affording unequivocal evidence of the persistence of the digestive process.

Nor does the section of these nerves destroy the secretion of the gastric fluid, for the matter vomited affords evidence of its having been mingled with acid, and the fact of the formation of chyle proves that stomach digestion must have taken place. Müller and Dickhoff, in their experiments upon section of the vagi in geese, found the fluid secreted by the stomach distinctly acid. In Dr. Reid's experiments, the ordinary mucous secretion of the stomach was found in its usual quantity, and when arsenic was administered to the animals, the mucous secretion was quite as abundant as in others in which the vagi nerves were not cut.

The few pathological facts which can be collected of diseased states of the vagi nerves are confirmatory of the conclusions deducible from anatomy and experiment. Several instances are recorded of loss of voice and dyspnœa, symptoms resembling those of chronic laryngitis, caused by the compression of the recurrent by an aneurismal or other tumour. The violent convulsive cough, which accompanies enlarged bronchial glands, is probably due to the irritation of the pulmonary branches of the vagi nerves. Hooping-cough is probably an affection of the vagi nerves by a peculiar poison. Dr. Ley attributed the phenomena of laryngismus stridulus to the irritation of enlarged cervical glands, affecting the recurrent nerves, and there seems no doubt that, although the symptoms of this disease occur more frequently as part of a peculiar exhausted state of system, they may be, and are, produced sometimes by the local irritation of such gland.

The diseases in which this nerve is involved are chiefly those which affect its gastric and pulmonary branches. The sympathy which all practitioners admit to exist between the digestive and respiratory organs is explained by the anatomical relations of this nerve. Asthma is essentially an irritation of the centre of respiration and of this nerve; this disease almost invariably begins by some deranged state of digestion, or by the introduction of some poisonous material from without; some very subtle material suspended in the air, and brought by inhalation into contact with the respiratory surface, for example, the minute particles which pass off from powdered ipecacuanha, or from hay. Asthma and intermittent fever often go together, because the marsh poison which gives rise to the one, may likewise excite the other. Asthma, which has occurred once, is easily reproduced by irregularities of diet, and consequent disturbance of digestion; and the frequent recurrence of the asthmatic paroxysm causes the dilated state of the air-passages and air-cells of the lungs, the dilation of the right cavities of the heart, and the general displace-

ment of that organ, which are invariably present in persons who have long been subject to this disease. Vomiting may be excited by irritation of the central or the peripheral extremity of this nerve. In disease at the base of the brain, vomiting is frequently an early symptom, being caused by irritation of the central extremity of the vagus. In sea-sickness the cerebral extremity of the nerve is irritated by the disturbance of the circulation in the cranium. By introducing emetic substances into the stomach, the vomiting is produced by the irritation of the peripheral extremity.

Many of the actions in which the vagus nerve is concerned are of the physical kind. Of these, œsophageal deglutition is the most marked. The closure of the glottis upon the application of any stimulus to its mucous membrane, is another example of the same nature. But in both these instances, and in all the movements with which this nerve has to do, sensation accompanies the act. In œsophageal deglutition, there is less sensation than in the other movements, but it is, nevertheless, present, particularly in case of any impediment being offered to the passage of the food. With reference to the movements of the glottis, it is interesting to remark, that whilst the will exercises a minuteness of control over them which is only surpassed by the power which it has over those of the fingers, it is only *closure* of the glottis which is caused by a physical stimulus. The obvious explanation of this is derived from the great preponderance of the constrictor over the dilator muscles of the glottis.

On what grounds Dr. M. Hall asserts that "the vagus nerve is certainly the least sentient of any in the class vertebrata,"* we are at a loss to discover. We do not hesitate to affirm that every act of an excitor kind, in which it is concerned, is accompanied by sensation, which in some is exquisite, in others feeble. Nor can we derive, either from the anatomy or physiology of this nerve, any confirmation to his hypothesis of a special series of excitor and motor nerves. It is well known that continued stimulation of the pharyngeal portion of the glosso-pharyngeal nerve upon the fauces will produce the feeling of nausea, and even vomiting. Nausea is a feeling, accompanied by a particular condition of the muscular coat of the œsophagus and stomach, preparatory to vomiting, and may be produced by a certain degree or kind of stimulation of any part of the mucous membrane from the fauces to the stomach. The vagus as well as the glosso-pharyngeal, is the instrument of this sensation; for the latter nerve has not sufficiently extensive connections to justify the supposition that it is the sole agent. And this may be cited as a most striking instance of the sensitive endowment of the vagus.

The following conclusions may be adopted respecting this nerve and its branches.

1. That the vagus nerve contains filaments both of sensation and motion.

2. That its pharyngeal branches are motor.

* The whole passage is, "This nerve (the vagus) is certainly the *least* sentient, and the *most* purely excitor, of any in the class vertebrata."—*New Memoir on the Nervous System*, Adv. p. 9.

3. That its superior laryngeal branch is the sensitive nerve of the larynx, containing a few motor filaments to the crico-thyroid.

4. That the inferior laryngeal is the principal motor nerve of the larynx.

5. That the cardiac branches exert a slight influence on the movements of the heart.

6. That its pulmonary branches contain both motor and sensitive filaments, and exercise an important influence upon the respiratory acts, for they cannot be destroyed without retarding materially the respirations, impeding the passage of the blood through the lungs, and causing œdema of these organs.

7. That its œsophageal branches are the channel through which the muscles of that tube are excited, through the medulla oblongata, to contract.

8. That the gastric branches influence the movements of the stomach, and probably in some degree the secretions and the sensibility of its mucous membrane; but that their integrity is by no means essential to the continuance of the secretion, or to complete chymification.

Of the Spinal Accessory Nerve.—The term *spinal* is applied to this nerve because of its extensive connection with the upper part of the spinal cord. It escapes from the cranium along with the vagus through a common opening in the dura mater; but its roots are implanted in the side of the medulla oblongata, and of the cervical region of the cord as low as to the level of the fifth or sixth cervical nerve. On examining the side of the upper part of the spinal cord, the fascicles of origin of this nerve are seen emerging from it, in the interval between the ligamentum denticulatum and posterior roots of the spinal nerves. The lowest fascicles are those nearest to the posterior roots of the lower cervical nerves. By the union of all the fascicles the nerve is formed, and it enters the cranial cavity from that of the spine through the foramen magnum.

Sometimes some of the upper roots of the spinal accessory nerve coalesce with the posterior roots of the suboccipital and the second and third cervical nerves. This appears to be nothing more than a junction of the fibres of two nerves which emerge from the nervous centre in close proximity to each other.

Very shortly after the escape of the spinal accessory nerve from the foramen lacerum, it divides into an *internal* and an *external* branch. The former coalesces with the vagus, where its second ganglion is formed, and, according to some physiologists, supplies the motor branches of that nerve; the latter passes outwards and downwards, through the deeper fibres of the sterno-mastoid muscle, to which it gives some branches, and anastomoses with branches of the second and third cervical nerves; and having crossed the triangular space in the neck between the sterno-mastoid and trapezius, it penetrates the latter muscle at its deep surface, and is distributed in it, anastomosing with other branches of the cervical plexus.

We learn from the anatomy of this nerve that it supplies two great muscles, which play an important part in effecting certain movements

of the head and shoulder, and, in a secondary manner, contribute to the actions of respiration, especially to those of a forced or extraordinary kind; and likewise that it forms a junction with the vagus nerve by a branch which consists of a considerable number of fibres.

There can be no doubt, from anatomy, that those fibres of the nerve which pass to the trapezius and sterno-mastoid muscles, are principally motor, for their main distribution is to these muscles; and all experimenters agree in stating that, whenever stimulated, they excite these muscles to contract. Anatomy, however, equally indicates that these muscles derive motor power from branches of the cervical plexus likewise.

The office of the internal branch, which incorporates itself with the vagus nerve, is not so easily determined. Scarpa, Arnold, Bischoff, Bendz, and others, viewed it as contributing the motor fibres to that nerve, bearing to it the same relation as the anterior to the posterior root of a spinal nerve.

An objection to this view, although not an insuperable one, is suggested by the origin of the nerve, which seems more in accordance with that of the posterior roots of the spinal nerves than with their anterior roots, and this is especially the case with the lower fascicles of origin which emerge from the cord quite close to the posterior roots of the cervical nerves. The reply to this objection is, that the external branch of the nerve is nevertheless distinctly motor, and that therefore the internal may be so likewise. Morganti and Bernard affirm that the lower roots form the external branch; if so, then the superior fascicles may be those which contribute to form the internal branch, and, therefore, its function probably differs from that of the external branch. We have already alluded to the fact that a coalition is sometimes observed between the posterior roots of the first or second cervical nerves, and the upper roots of the spinal accessory. The function of the former being confessedly sensitive, it is highly probable that the latter nerves, which are apt to coalesce with them, should perform a similar office.

To determine this question by experiment is extremely difficult by reason of the small size of the internal branch and the great depth at which it is situate, which render it almost impossible to expose the nerve without injuring the vagus itself. Accordingly, we find the recorded statements of physiologists regarding the results of such experiments, quite contradictory. The greatest number of observers, and the most recent ones, give their evidence against the motor function of the internal branch, at least against the doctrine of its yielding the motor fibres of the vagus nerve. Most of them, however, agree in stating that a degree of hoarseness and feebleness of voice always followed the section of the internal branch, as if *some* of the motor fibres of the laryngeal nerves were derived from it. From Müller's and Dr. John Reid's experiments, by irritation of the spinal accessory nerve within the cranium, no conclusive results were obtained favourable to the view which assigns motor power to the internal branch; on the contrary, these experiments rather tend to prove that the vagus contains within itself the motor fibres sufficient for the parts it supplies. These experimenters found that irritation of the trunk of

he vagus, *before* its junction with the spinal accessory, caused contractions of the pharyngeal and laryngeal muscles, as well as of the bres of the œsophagus.

Respecting the external branch of the spinal accessory nerve, it as been already stated that experiment confirms the results deducible rom anatomy. We know that the trapezius and sterno-mastoid muscles receive nerves from the cervical plexus as well as from the spinal ccessory. If the latter be cut, these muscles are not paralyzed, lthough weakened, and continue to act in respiratory as well as in oluntary movements, contrary to the views of Sir C. Bell, who egarded the spinal accessory nerves as special nerves of respiraion, whilst those of the cervical plexus were nerves of volition. There are, indeed, no good grounds for coming to any other conclusion than that which Dr. John Reid arrives at; namely, that the xternal branch of the spinal accessory exactly resembles, in its funcions, the branches of the cervical plexus with which it so freely nastomoses.

It may be fairly asked, however, why do the trapezii and sternoastoid muscles receive their nerves from a double source? The nost reasonable reply to this is, that while the branches of the cerical plexus serve to connect these muscles with the centres of voliion and sensation in the ordinary way, the external branch of the pinal accessory connects it in a more direct manner with the centre f respiration. Nevertheless, this branch, although especially imlanted in that centre, is capable of obeying voluntary impulses, so ong as the medulla oblongata maintains its normal relation to the entre of volition.

Thus, on the whole, we assign motor power to the external branch f the spinal accessory, but we see no good reason to subscribe to e opinion that its internal branch must be regarded as the *motor oot* of the vagus. Indeed, we are much more disposed, for anaomical reasons, to regard the office of this branch as totally different. None of the views hitherto put forward respecting this nerve explain e object of its peculiar and most extensive connection with the nervus centre; a connection which, in the larger quadrupeds, is still ore extensive than in man. Our view is as follows: the internal ranch of the spinal accessory consists of *afferent* fibres, which, onnected with the sensitive surface of the respiratory organs, pass owards the centre in the trunk of the vagus, but separate from at nerve to be implanted in a large extent of the respiratory cene. This mode of implantation of the spinal accessory nerve serves bring the sentient surface of the lungs and air passages into imediate relations with the roots of all those nerves which animate e great muscles of respiration, the phrenic, the external thoracic, e cervical plexus, and the motor fibres of the spinal accessory and agus nerves.

Respecting the subjects discussed in this chapter, the systematic works on escriptive Anatomy and Physiology may be consulted; also Sir C. Bell's and ayo's works, and Dr. Reid's Essays in the Edinb. Med. and Surg. Journal; Dr. arshall Hall's writings; the Article "Par Vagum," in the Cyclopædia of Anatomy nd Physiology.

CHAPTER XXI.

THE SYMPATHETIC NERVE. ITS ANATOMY AND FUNCTIONS.

UNDER the title of Sympathetic nerve is comprehended a great subdivision of the nervous system, which presents certain peculiarities of structure and of distribution, whereby it is strikingly contrasted with the strictly cerebro-spinal nerves.

It consists of an uninterrupted chain of ganglia, extending on each side of the vertebral column, from the first cervical vertebra down to the coccyx, and moreover extending upwards beside the cranial vertebræ, and occupying spaces between the bones of the cranium and those of the face.

The ganglia are on the whole rather less numerous than the vertebræ: in the dorsal region there is generally a ganglion for each vertebra. The continuity of the chain is preserved by cords of communication which pass from one to the other: sometimes two ganglia are, as it were, fused together; the chains of opposite sides communicate with each other at various parts in the plexuses of nerves which originate from them, and, in front of the coccyx, through a single ganglion (*ganglion impar*), which is situate in front of that bone; whether they communicate at the cephalic extremity, or not, is uncertain. Ribes has described a *ganglion impar* upon the anterior communicating artery of the circle of Willis, similar to that on the coccyx, and other anatomists regard the pituitary body in the sella Turcica as a ganglion of this description, a common point of union for the right and left sympathetic chains at their cranial extremities.

The sympathetic nerve has very much the same general arrangement in mammalia and birds as in man. In the former the cervical portion is closely associated with the vagus nerve by a sheath of areolar tissue, but without interchange of fibres, excepting at its upper portion. In birds the cervical portion exists only in the canal formed by the foramina of the transverse processes of the vertebræ. In the batrachian reptiles the sympathetic is disposed as in mammalia. In the chelonian reptiles its ganglia are few and the lateral cords small. In serpents it appears to want the distinct ganglia which exist in other animals; it is, however, continued down the spine on each side, having frequent communications with the vagus. Numerous plexuses occur in its course. In the larger osseous fishes the sympathetic is sufficiently distinct, as in the cod; it is also present in the ray; in both, but especially the latter, it is the abdominal portion which is chiefly developed.* In the cyclostomatous fishes the sympathetic is said to be wholly deficient.

For the sake of description, the sympathetic in the human body may be divided into the following portions: 1. The Cephalic. 2. The Cervical. 3. The Dorsal. 4. The Lumbar. 5. The Sacral.

In comparing these several portions, we find that they have certain characters in common. Each portion consists of its proper number of ganglia, which seems in some degree influenced by the num-

* See Mr. Swan's beautiful Plates of the Comp. Anat. of the Nervous System.

rtebræ in that region of the spine to which it belongs. The are connected by cords of communication, which are not ves, but are true extensions of the ganglia in a cord-like that each lateral chain might be described as a continuous , with swellings at certain intervals. From each portion ets of nerves may be pretty constantly traced: these are, the cords of communication between the ganglia, 1. *Visceral* which generally accompany branches of neighbouring arteries iscera. 2. *Arterial* nerves, apparently devoted to arteries cinity of the ganglia. 3. Nerves of communication with the or spinal nerves, which emerge from the cranium or spine ıe ganglia.

isceral and arterial branches have a remarkable tendency to xuses, generally very intricate, which entwine around the ssels, and, in the former case, are conducted by them to the the viscera.

ranches of communication with cerebral or spinal nerves, ıg the most remarkable connected with this portion of the system. We have already (p. 205) described certain of consisting very distinctly of two portions or bundles, one l of tubular fibres, the other almost exclusively of gelati- es. These bundles have been very commonly described as ng the roots of origin of this nerve.*

cing back the gray bundle, connected with one of the spinal : is found that most of its fibres go to the ganglion of the root of the nerve, some passing into the anterior root. A ese fibres may be found in each root; they are not, however, into the spinal cord, but seem to connect themselves only ›lood-vessels of that organ. Such is probably the anatomical ' the so called gray root of the sympathetic connected with nal nerve. It may, therefore, be more justly regarded as a ginating from the sympathetic ganglion, which by some of connects that ganglion to the ganglion on the posterior ›t, and by others is distributed to the vessels of the cord. e conclusion which Mr. Beck's recent researches have led opt, and the careful examination of his very able dissections s to believe this to be the correct view.

hite root, or the bundle of tubular fibres, when traced to the rve, appears like a branch of it, i. e. a series of fibres, sepa- m it, and passing to the sympathetic. It derives fibres in ual numbers from the anterior and the posterior root. In tance it may be seen, spreading out upon the adjacent sym- ganglion, passing through its vesicular matter, and following e of the trunk of the sympathetic for a longer or shorter then proceeding from it in connection with its gelatinous efly to viscera. Mr. Beck informs us that he can, under the ›e, distinctly trace the continuity of these fibres *through* the

figure of these roots is given in Wutzer's work, "De Corporis humani fabrica atque usu." Wutzer does not, however, distinguish them as ray. Berlin, 1817.

ganglion, and he is of opinion that they do not form any organic connection (as some fibres in ganglia and other nervous centres undoubtedly do) with the vesicles of the ganglion, beyond that which might result from passing between them. These fibres, then, according to this statement, must be regarded as a branch of the spinal nerve, distributed, in connection with gelatinous fibres derived from the sympathetic ganglion, to viscera and other parts.

If this view of the anatomical relation between the sympathetic ganglia and the cerebro-spinal nerves be correct, it seems evident that the proper sympathetic fibres must be viewed as a separate portion of the nervous system, consisting entirely of gelatinous or nucleated fibres which originate in the vesicular matter of the sympathetic ganglia. These fibres, however, are accompanied in their course by tubular fibres, derived from the cerebro-spinal nerves, which pass over or through the sympathetic ganglia without forming any intimate connection with them, and which are distributed along with the gelatinous fibres to viscera and other parts.

1. *Of the Cephalic portion of the Sympathetic.*—This portion of the sympathetic consists of ganglia, which occupy different parts of the head, and are connected with each other, and with the superior cervical ganglion. They are four in number:—

1. The ophthalmic ganglion. 2. The spheno-palatine, or Meckel's ganglion. 3. The otic ganglion, discovered by Arnold. 4. The submaxillary ganglion.

The *ophthalmic*, or *lenticular*, or *ciliary* ganglion is found in the orbit, situate on the outer side of the optic nerve, a little way before its entrance into the eye, enveloped in soft fat. It is a small quadrangular ganglion, of a reddish colour, not unlike a pellet of fat, for which it may be very readily mistaken by an inexperienced dissector.

Numerous nerves proceed from the anterior angles of this ganglion to the eyeball. These are the ciliary nerves, which have been already described, p. 423.

The ophthalmic ganglion is connected with the third nerve, and with the nasal branch of the ophthalmic division of the fifth. The branch of communication with the third nerve is a short thick nerve which comes from the inferior branch of that nerve: it is called by descriptive anatomists, *the short root* of the ganglion. From the nasal nerve proceeds *the long root*, a long and very delicate nerve, which attaches itself to the superior posterior angle of the ganglion.

We have not examined by the microscope the constitution of these branches of connection with the third and nasal; but it is not uninteresting to notice that several anatomists have remarked, in reference to them, that the place of each is occasionally supplied by two, which may answer to the two connecting nerves already noticed, in the dorsal portion of the sympathetic.

By means of a third filament called by some *the middle root*, this ganglion is brought into connection with the cavernous or carotid plexus from the superior cervical ganglion.

The *sphenopalatine* ganglion is situate in the pterygo-maxillary fossa; it is a small, somewhat triangular, ganglion connected with

infra-orbital nerve, at its crossing over the spheno-palatine fissure, ass along the floor of the orbit. This connection is effected by or three short nerves called commonly the spheno-palatine iches of the infra-orbital nerve.

'rom this ganglion proceed, first, *palatine* nerves, which are three iumber (anterior, middle, and posterior), which pass through the erior palatine canal, to be distributed to the mucous membrane he hard and soft palate, and also to the nasal mucous membrane. ondly, *nasal* branches, described by Scarpa, which enter the nose ugh the spheno-palatine foramen, and distribute branches to the igy bones, and to the septum. One of these, the naso-palatine 'e, passes obliquely downwards and forwards, along the septum, enters a canal in front of the foramen incisivum, through which isses to subdivide in the mucous membrane of the hard palate. rdly, the *vidian* nerve, which, coming off from the posterior part of ganglion, passes through the vidian canal, and divides into two iches, the superior, or *the great superficial petrosal nerve*, which rs the cranium, and under cover of the dura mater, passes through hiatus Fallopii, to unite itself with the geniculate swelling of the io dura;* and the inferior, or *carotid branch*, which enters the us around the carotid artery, and thus forms the bond of union reen the spheno-palatine and the superior cervical ganglion; this r branch is much the larger. Arnold states that this ganglion is coned with the optic nerve, and also with the ophthalmic ganglion.

he Otic Ganglion.—This ganglion, discovered and described by old, lies at the inner and inferior part of the inferior maxillary sion of the fifth nerve, just at its exit from the foramen ovale. It mnected with this nerve by two filaments, which Arnold consito be derived from the fibres of the lesser portion of the fifth nerve. des branches to the internal pterygoid, and the tensor palati cles, it sends a filament into the cranium which passes through hiatus Fallopii into the cavity of the tympanum, and there anasnes with the tympanic branch of the glosso-pharyngeal. This is *lesser superficial petrosal nerve*, which Arnold regards as an emaon from the glosso-pharyngeal, and as a root for the ganglion, ogous to the long root of the ophthalmic ganglion. The precise iection of this ganglion with the sympathetic has not been clearly e out. It contains numerous gelatinous as well as tubular fibres, its vesicles are large and distinct.

he Submaxillary Ganglion.—This ganglion is occasionally reed by a plexus of nerves. One or two fibres from the gustatory 'e constitute its roots, and its principal ramifications are distributed ie submaxillary gland. It is connected with the superior cervical glion through the cavernous plexus.

Of the Cervical portion of the Sympathetic.—This consists of e ganglia on each side, the middle of which is by no means cont. The *superior* is the largest, and extends from within an inch

* is probably from this source that this swelling receives the many gelatinous ; already described.

of the inferior orifice of the carotid canal, to the third cervical vertebra, and sometimes as low as the fourth or fifth. It is connected by large branches with the first, second, and third cervical nerves; from its upper extremity there passes upwards into the carotid canal a branch which divides into two that accompany the carotid artery, dividing and subdividing as they ascend, so as to form a plexus around that artery, *the cavernous or carotid plexus*. With this plexus numerous communications take place: there is one with Meckel's ganglion, another with the tympanic plexus; a branch to the ophthalmic ganglion, and one or two large ones to the sixth nerve, which formerly were regarded as roots of the sympathetic from that nerve; also one or two filaments to the third pair, and small branches attaching themselves to the ramifications of the carotid artery within the cranium. Communications exist between the superior cervical ganglion, and the several portions of the eighth pair, and the ninth pair at their exit from the cranium.

Inferiorly the superior cervical ganglion is continued into a cord of communication with the middle, or, when that is wanting, with the inferior cervical ganglion.

The arterial and visceral branches of the superior cervical ganglion, are, 1. The delicate gray nerves to the internal carotid artery, (*nervi molles* of Scarpa,) which, with branches from the glosso-pharyngeal and vagus, form a plexus round the internal, external and common carotid arteries. 2. Pharyngeal branches, which, with filaments from the vagus and glosso-pharyngeal, form the pharyngeal plexus. 3. Laryngeal branches accompanying the superior laryngeal branch of the vagus. 4. A cardiac nerve, not always present, and very variable in size, (*the superior cardiac nerve* of Scarpa,) which, either united with a similar nerve from the middle, or inferior cervical ganglion, or alone, passes along the carotid artery into the chest, to contribute to form the plexus of nerves belonging to the heart.

The middle cervical ganglion is very inconstant; it is placed opposite the fifth or sixth cervical vertebra, and besides the branches of continuation with the third, fourth, and fifth cervical nerves, it gives off one visceral branch, namely, the middle cardiac nerve, (*nervus cardiacus magnus* of Scarpa,) which is the largest of the three, and in default of the ganglion, comes off from the intercommunicating cord. This nerve has a similar course to the inferior one; it is often absent, and its place is then supplied by filaments, which take a similar course, but are derived from the superior nerve, or from the vagus.

The inferior cervical ganglion.—This ganglion is situate very low down in the neck, and is very deep seated; it corresponds to the transverse process of the last cervical vertebra, to the head of the first rib, and is closely connected with the origin of the vertebral artery. It is frequently fused with the first thoracic ganglion, and is connected above with the middle, or, in its absence, with the superior cervical ganglion. It is connected with the fifth, sixth, and seventh cervical nerves, and sometimes with the first dorsal.

The arterial and visceral branches of this ganglion are, 1. A nerve

ompanies the vertebral artery into the canal formed by the processes of the cervical-vertebræ. This nerve forms a ınd the vertebral artery, and communicates with branches e lowest cervical nerves. There is no satisfactory evi- t this nerve passes up to the arteries of the brain. It seems nerve to the vertebral artery, but doubtless also contains ı the cervical spinal nerves, which probably have a differ- ation. 2. The second branch of this ganglion is the third *cardiac* nerve which passes down, frequently in company middle cardiac nerve, to the plexus on the heart. 3. which encircle the subclavian artery, in the first part of

ɔrthy of note that the most important visceral branches of al portion of the sympathetic, are destined to an organ, the ich is situated in the thorax at a considerable distance from ce.

Thoracic portion of the Sympathetic consists of a series of orresponding, or nearly so, in number to that of the ver- e ganglia lie upon the heads of the ribs, and are mostly ize, and triangular in form. The first thoracic ganglion is d with the last cervical.

ı the branches of communication with the spinal nerves, arterial branches which pass to the aorta, and there are also which pass into the pulmonary plexus.

most remarkable nerves which proceed from these ganglia, *eater* and *the lesser splanchnic nerves.*

eat splanchnic nerve arises by separate roots, probably from ɔracic ganglia, more obviously from the fifth, sixth, seventh, ıd ninth; these roots unite to form a round cord, as large, ger, than the trunk of the sympathetic. This nerve passes of the bodies of the vertebræ obliquely downwards and enters the abdomen by piercing the diaphragm, and ends and complex ganglion placed by the side, and in front of close to the origin of the cœliac artery; this is the *great ganglion.**

sser splanchnic nerve takes its rise by two roots from the and twelfth, or from the tenth and eleventh ganglia; it wn in a similar course to the larger nerve, parallel to, and pierces the diaphragm, and unites with the renal plexus of ıd with the aortic plexus.

mposition of this nerve deserves particular attention as illustrating the ıature of the ramifications of the sympathetic. It may be regarded as te of a series of visceral nerves proceeding from the intercostal nerves, ch, as it passes over the sympathetic ganglion immediately adjacent to the which it arises, becomes associated with some gelatinous fibres. Thus, intercostal nerve contributes certain tubular fibres, each thoracic ganglion gelatinous fibres. Sometimes these two sets of fibres are kept distinct, ınchnic nerve consists obviously of a white and a gray portion. The gela- s are considerably more numerous at the lower than at the upper part of nic nerve, as pointed out by Mr. Beck, who very justly cites the fact as ıfirmatory of the statement that these fibres arise from the ganglia.—*Phil.*), p. 224

The striking analogy between these nerves and the cardiac nerves cannot fail to attract the attention even of the most superficial observer. The latter nerves, distributed to an important organ in the thorax, have their rise in the neck; and the splanchnic nerves, deriving their origin from nearly all the thoracic ganglia, are devoted to important viscera of the abdomen.

Of the Lumbar and Sacral portions of the Sympathetic.—The chain may be followed down to the coccyx; the lumbar ganglia are small and irregular in number. The continuity of the chain between the lumbar and dorsal segments, is maintained sometimes by a small intercommunicating cord, between the last dorsal and first lumbar ganglion, which pierces the diaphragm, sometimes by a branch of the greater or lesser splanchnic, which of course establishes the continuity indirectly. The branches of communication of these nerves with the lumbar spinal nerves, are sufficiently distinct, and some of them are of great length. The gray branches are, according to Beck, larger than the corresponding ones in the thorax.

The nerves which come from the lumbar portion of the sympathetic are destined to the aorta, and to the lumbar arteries; the greater part of them form a plexus around the aorta, between the mesenteric arteries, from which proceed fibres to form the *inferior mesenteric plexus*, which follows the inferior mesenteric artery; below this artery the aorta is still embraced by a plexus (*inferior aortic plexus*) which divides into the *hypogastric plexuses*, one on the right and the other on the left, which supply the rectum and bladder, the organs of generation, and the accessory parts. At the base of the coccyx, the sympathetic of the right side anastomoses with that of the left by means of a branch passing on each side from the last sacral ganglion to a ganglion in front of the coccyx, which is called the *ganglion impar*.

Of the Thoracic and Abdominal Plexuses.—So large a portion of the sympathetic is distributed to viscera in the thorax and abdomen, that it may not improperly be designated as the *visceral nerve;* for those organs, upon which the great processes which contribute to the nutrition of the body so much depend, derive their nerves mainly from this source, and whatever cerebro-spinal fibres they receive, are distributed to them in intimate association with the proper filaments of the sympathetic.

The plexuses in the thorax which derive nerves from the sympathetic are the pulmonary plexus, and the cardiac plexus.

The *pulmonary plexus* is chiefly formed by branches of the vagus, interlacing with each other from opposite sides along the median plane. It occupies two planes, one anterior to the bronchi constituting the *anterior* pulmonary plexus, the other *posterior*, which is much the more considerable, and lies behind the bronchi. To these, but especially to the latter, nerves pass off from the higher thoracic ganglia.

The *cardiac plexus* is almost wholly derived from the sympathetic, only a few of its fibres coming from the cardiac branches of the vagi. It is very remarkable that all the nerves which the sympathetic con-

tes to this plexus, are derived from the cervical, and not from ıoracic ganglia. The plexus resulting from the anastomoses of nerves, occupies an anterior and a posterior plane; the former ng in front of the great arteries, and following the course of the ior coronary artery, in the anterior groove of the heart. The ıs entwines around this artery and its ramifications, and its fibres oubtless conducted by them to the muscular fibres of the heart. posterior plexus follows the course of the right coronary artery, ›f its branches, which lies in the posterior fissure of the heart. :xus of fibres, occupying a position intermediate to these plex- lies behind the arch of the aorta, above the right pulmonary, and ı a considerable plexus of nerves to the auricles. This plexus lescribed by Haller, as *the great cardiac plexus.*

veral small ganglia, or *gangliola*, are found in connection with erves of the heart. Wrisberg described one just above the of the aorta, at the junction of anastomosing fibres from the ior cardiac nerves. A ganglion is also sometimes found in the ıs in front of the auricles, and Remak describes and figures al small ganglia upon the subdivisions of the anterior and pos- cardiac plexuses, and in the muscular substance of the heart. er's *Archiv.*, 1844.

ıe nervous plexuses in the abdomen are extremely complicated ıumerous. They are principally derived from two great gan- situate on each side of the cæliac axis, in front of the aorta. e ganglia are semilunar in shape, convex downwards and out- s; they unite below the cæliac axis; and chiefly from their ex border, a vast radiation of plexiform nerves takes place, which v the course of, and entwine around the branches of the cæliac and of other branches of the aorta. To this great radiation mists have given the name of *solar plexus*, and the conjoint semi- ganglia must be looked upon as the great centre,—the sun of bdominal sympathetic system.

ıxuses radiate from this source around the principal branches : aorta, and they are named after the arteries which they accom- . They are the *diaphragmatic* or *phrenic;* the *supra-renal;* the *c;* which divides into the *hepatic*, *gastric* and *splenic;* the *supe- nesenteric*, from which proceed nerves, which, with others from umbar portion of the sympathetic, form the *inferior mesenteric* s; and the *renal plexuses*, from which chiefly are derived the *natic plexuses*, destined to the ovaries in the female, and the les in the male. Of these plexuses the following are deserving re particular notice:

e *gastric* plexus accompanies the coronary artery of the stomach, ıasses along the lesser curvature of that organ. With the gastric :hes of the vagus it forms the principal nervous supply to the ıch, which is completed by an off-shoot surrounding the right ›-epiploic artery from the hepatic plexus, and by other nerves the same plexus distributed chiefly to the pylorus, and by :hes from the splenic plexus.

e *hepatic* plexus follows the hepatic artery and the vena portæ

into the substance of the liver; it is joined by a branch of the vagus; and it gives off nerves to the stomach, and to the pancreas.

The *splenic* plexus surrounds the splenic artery, supplies the pancreas, and the left extremity of the stomach, by entwining round the the left gastro-epiploic artery, and by direct branches to the great cul-de-sac of the stomach. These nerves then follow the branches of the splenic artery into the spleen.

The *superior mesenteric* plexus supplies the greatest portion of the intestinal canal, entwining around the superior mesenteric artery and its ramifications. Connected with it are some ganglia of variable size, called *cœliac* or *mesenteric ganglia*. From these ganglia, and from the upper part of the plexus, nerves are derived to the pancreas, and to the duodenum.

The branches of this plexus which pass between the laminæ of the mesentery do not accompany the smaller branches of the arteries so closely as elsewhere. They anastomose by arches, from which small branches pass to the intestine. The precise mode of termination of these nerves in the tunics of the intestines has not been ascertained.

In the pelvis we find a remarkably complicated plexiform arrangement of nerves distributed to the viscera of that cavity. These nerves are derived from the *hypogastric* and from the *inferior mesenteric* (p. 504), and receive many fibres from the sacral nerves, which latter fibres are principally distributed to the pelvic plexus, a name given by Mr. Beck to an intricate anastomosis of nerves and small ganglia distributed to the rectum, bladder, and vagina. This plexus derives its nerves from the lower part of the hypogastric plexus, and from the branches of the sacral plexus.

A very important peculiarity of all the plexuses, wherever found, of the sympathetic nerve, consists in the presence of a quantity of vesicular matter in them, deposited in ganglia of very variable size, sometimes extremely minute, very rarely of great size, which are found scattered amongst them. These ganglia appear to give origin to gelatinous fibres. The plexuses, therefore, have the double office of intermingling fibres from different sources, and of affording points of origin for new nerve fibres.

Function of the Sympathetic Nerve.—In considering the function of this portion of the nervous system, it is of the utmost importance to pay close attention to the facts which the anatomical analysis of it discloses.

These facts are, that it contains a vast number of centres to and from which nerves proceed, and in which, it may be stated almost with certainty, gelatinous fibres originate: that in nearly every part of it two kinds of fibres exist, the gelatinous and the tubular; that the tubular are derived from the cerebro-spinal centre, the gelatinous from the sympathetic ganglia.

Two questions are to be solved in reference to the sympathetic.

1. Is the sympathetic a distinct and independent portion of the nervous system? or is it merely an off-shoot from the brain and spinal cord, exhibiting certain peculiarities of arrangement?

2. Do its fibres exhibit the same powers as those of cerebro-spinal ɜrves? that is, are they sensitive and motor?

I. No physiological question has been more amply discussed of te years than that of the relation of the sympathetic to the cerebro-ɪinal centres.

The view, which we regard as the correct one, rests entirely upon ɪe facts of anatomy already stated. These facts lead us to consider e sympathetic nerve a compound nerve, consisting of gelatinous ɪres, which are derived from the vesicular matter of the ganglia, ɪd of tubular fibres, proceeding from the spinal cord. These fibres e bound together in the same sheath, and whatever be the proper ɒction of each, they bear to each other a similar relation to that hich the anterior and posterior roots of spinal nerves do in the ɪmpound nerve. Originating from different sources, and possess-g probably different endowments, they travel in company to their veral destinations.

We are aware that some physiologists of high and deserved re-ɪte altogether deny that the gelatinous fibres, which we have de-ribed as entering so largely into the constitution of the sympathetic, e nervous. They regard them as an early stage of fibrous or eolar tissue. The following reasons appear to us quite decisive of e nervous nature of these fibres. 1. They may be distinctly traced the vesicular matter of ganglia; it is immaterial to the question hether they form their connection with the sheaths or with the ɜsicles themselves, for we are as much at liberty to regard the ɪcleated envelope of the vesicles as a structure essentially nervous the vesicles themselves. Parts of the encephalon appear to consist little else than nuclei.

2. Throughout the sympathetic system these fibres and the tubular ɪres exist in the several nerves in different but determinate numbers. ɪmetimes the two kinds are equal, sometimes one predominates over e other; sometimes the nerves consist solely of gelatinous fibres. ow if these latter performed the office of a sheath or support to the bers, they would always be in due proportion to each other. More-ver, the gelatinous fibres would be always outside, enveloping the bular, which is not at all uniformly the case.

3. Nucleated fibres, very similar to the gelatinous fibres of the mpathetic, exist in parts where their nervous character is indubitable, in the olfactory filaments (p. 397), and the nerve in the axis of the ɪcinian corpuscle exhibits very much the same appearance, save at it is devoid of nuclei.

Adopting this view of the compound nature of the sympathetic, is obviously impossible to regard it either as independent of the ɜrebro-spinal centres, or wholly depending on them. It seems pro-ɪble that it is independent of them as regards its gelatinous fibres, ɪt dependent on them as regards its tubular fibres.

And it may be stated that the views of anatomy which we hold be correct, justify us in affirming that the sympathetic exhibits arked indications if not of independence, yet of great peculiarity, its mode of distribution. Clinging to the coats of arteries, it

follows them for the most part in their ramifications, and attaches itself to them somewhat as ivy does to a tree. Yet of the mode of termination of the gelatinous fibres of the sympathetic, and of the nature of their relations with the elements of the tissues among which they lie, nothing certain is known; a fact attributable in a great degree to their want of such obviously distinctive characters as the tubular fibres possess. These latter, after leaving the blood-vessels, are probably distributed either to sentient surfaces or to muscles in the ordinary way.

The proper mode, then, of stating the reply to this question seems to us to be: that the sympathetic, taken as a whole, is not in itself a special and independent nervous system, but a portion of the nervous system peculiar in its composition, having, as regards some of its constituent fibres, a special relation to blood-vessels, particularly arteries, (and these are the fibres which are independent of the cerebro-spinal centres, having distinct centres of their own,) but being by others of its fibres connected, as all other nerves are, with the cerebro-spinal centres.

II. The second question affects the endowments of the constituent fibres of the sympathetic.

If we interrogate anatomy, we learn that the ramifications of this nerve are distributed to muscles as well as to sentient surfaces. The heart, for instance, derives its principal supply of nerves from this source. The intestinal canal between the stomach and the lowest part of the colon receives no nerves direct from the cerebro-spinal system, and is therefore dependent solely on the sympathetic, for whatever of sensibility it enjoys, or for such motor power as may be usually called into action by nervous influence. We, therefore, must infer from anatomy that the sympathetic contains both sensitive and motor fibres.

Many experiments lead to a similar conclusion. Stimulation of the cervical ganglia excites the heart to increased action; and irritation of the splanchnic nerves causes increased vermicular motion in the stomach and intestinal canal. Müller proved a similar result to ensue upon irritation of the cæliac ganglion. He exposed the intestines, and likewise the cæliac ganglion in a rabbit; he waited until the increase of peristaltic action, which exposure to the air always produces, had subsided, and then he applied potassa fusa to the ganglion, when immediately the peristaltic movements became very vigorous. There is less agreement in the statements of the results obtained by different experimenters as to the sensibility of these nerves, as indeed is very commonly the case, when the question is respecting sensation; but the well known occurrence of pain in parts supplied only by the sympathetic, is alone more conclusive as to the existence of sensitive fibres in that nerve, than the results of any experiment on a brute animal. How exquisite are the sufferings of patients labouring under colic, or the passage of a gall-stone, or of a renal calculus!

It is plain, then, that the sympathetic nerve contains both motor and sensitive fibres. An appeal to common experience shows us,

t the latter cannot be very numerous, as parts supplied by the npathetic nerve are not, in the healthy state, highly sensitive, and n is felt in them only under the influence of great irritation. And h regard to the motor fibres, it shows that they are not at all, or at st to a very trifling extent, under the influence of the will. It is e that the will may be brought to bear upon muscles supplied by sympathetic, by directing it simultaneously upon other distinctly luntary muscles. This is well illustrated in the case of the iris; effort, however great, if directed solely upon the iris, will cause t muscle to contract, but if the voluntary influence cause a simuleous contraction of the internal rectus muscle of the eye, conction of the pupil will take place upon each adduction of the eyel.

It is highly probable that the increase in force and in frequency ich takes place in the heart's action, during active exercise, is to explained on the same principle; and that a strong effort of the ll directed to the abdominal muscles, may excite an increased istaltic action of the intestines.

Muscles supplied by the sympathetic nerve, although under ordiy circumstances referable to the category of involuntary muscles, st not then be considered as absolutely and entirely removed from influence of the will.

A very striking peculiarity, dependent in part probably upon the anaical arrangements of the sympathetic, consists in the *rhythmical* ure of the movements of parts which derive their supply of nerves m this source, of which the movements of the heart and the intesti- canal afford good examples. And it is an important feature of se actions that they take place even when the parts are disconted from the main portion of the sympathetic system. It is well own that the heart's action will go on for a considerable time after as been removed from the body; and that the peristaltic movents of the intestines will continue under similar circumstances.

This peculiarity seems to be referable to a double cause; first, the position of the muscular fibres themselves, which is such that a traction cannot take place at one part without affecting the adjacent res, so that the contraction of one set of fibres appears to stimulate se in their immediate vicinity. This progressive contraction is ll seen in the intestines. Secondly, the frequent occurrence of all ganglia, not only among the plexuses of the sympathetic, but o, as in the heart, upon or among the muscular fibres themselves. ese ganglia, it is reasonable to suppose, are so many little magaes of nervous force, which, by their intimate connection with the scular fibres themselves, render them capable of repeating their ion at intervals, after their disconnection from the main trunk of the npathetic system.

Much, however, in the peristaltic actions, is perhaps, due to the culiar constitution of the unstriped muscular fibre itself; a constiion which gives it a slow and enduring, rather than a quick, enertic, and fleeting contraction. The actions of the heart are interdiate to those of the intestine and of voluntary muscle, and so are

its muscular fibres, which, while they exhibit the striped appearance of voluntary muscle, are nevertheless devoid of the sarcolemma, and interlace in a peculiar manner with each other. The gelatinous nerve-fibres exhibit the same apparent inferiority of organization as the unstriped muscular fibre. It is a remarkable confirmation of these views, that in the tench (*Cyprinus tinca*), according to Ed. Weber, in which the muscular fibres of the alimentary canal are of the striped kind, there is no peristaltic action of the intestines, and that the application of a rapid succession of electrical shocks from a magneto-electric rotation instrument causes that sudden and quick contraction which characterizes the striped muscular fibre.*

An observation made by Pourfour du Petit,† many years ago, suggested an office of the sympathetic, distinct from sensation or ordinary motion, but apparently not less important than either. He found that the division of the trunk of the sympathetic in dogs, opposite the third or fourth cervical vertebræ, was followed, with remarkable rapidity, by a disturbance of the circulation in the eyeball; giving rise to a swollen and apparently inflamed state of the conjunctiva, a contracted state of the pupil, a flattening of the cornea, and a retraction of the eyeball, with protrusion of the fold of the conjunctiva, known by the name of the haw, and a flow of tears. Dupuy found similar effects resulting from the extirpation of the superior cervical ganglion in horses; and when the ganglia on both sides were removed, there were superadded to these more local effects, a general emaciation along with an anasarcous state of the limbs, and an eruption over the whole cutaneous surface.

Dr. J. Reid confirms these results of section of one sympathetic in the neck, as far as regards the eye, and he agrees with the other observers in stating that the injected state of the conjunctiva followed immediately after the section. In one case, he states that the redness of the conjunctiva took place *a few minutes* after the operation.

It has been already stated, that section of the branches of the fifth nerve, which supply the eye, is followed by ulceration and other signs of impaired nutrition in the eyeball. But these changes do not take place for some time after the section of the nerve; generally many days elapse: and they are attributable to the presence of irritating particles, which, owing to the insensible state of the conjunctiva, are suffered to remain in contact with the surface of the eye, giving rise to inflammation and ulceration of its textures. The effects of section of the sympathetic are *immediate;* and are probably due to a change produced in the blood-vessels, in consequence of the withdrawal of their accustomed nervous influence.

The sympathetic thus appears to exercise a threefold office: first,

* By experiments with the magneto-electric instrument, E. Weber has given additional illustration of the fact that the peristaltic contraction is characteristic of the unstriped fibre, and that the sudden and quick contraction is peculiar to the striped fibre. See his elaborate article "Muskelbewegung" in Wagner's Handwörterbuch, 1846, and our remarks at pp. 146, 149, 150.

† Histoire de l'Acad. Royal des Sciences, an 1727, &c. Lettres concernant des reflexions sur les découvertes faites sur les yeux, 1732.

that of a sensitive nerve to the parts to which it is distributed; secondly, that of a motor nerve for certain muscular parts; and, thirdly, that of a nerve to the blood-vessels. It is almost certain that blood-vessels enjoy in their coats a power of contractility; and it seems highly probable that these nerve-fibres exercise an influence upon that contractility. Such an influence, it is evident, would materially affect the nutrition of parts the blood-vessels of which are subject to it; and, as secretion is mainly dependent on the normal nutrition of glands, it is reasonable to suppose that that function likewise would be to a certain extent controlled by these nerves.

It remains to inquire the sources whence these various classes of fibres in the sympathetic respectively derive their powers.

Looking to the anatomy of the nerve, there can be no doubt that some fibres are derived from the spinal cord or medulla oblongata, and that others proceed from the sympathetic ganglia. The motor and sensitive fibres, and some of those going to the other muscular parts, belong, no doubt, to the former class; the vascular, with the highest probability, to the latter.

Valentin's experiments indicate that the roots of the encephalic and spinal nerves exert considerable influence upon the movements of parts supplied by the sympathetic. For instance, irritation of the roots of the first three or four cervical nerves, excites increased action of the heart; and that of the dorsal and lumbar spinal nerves stimulates the peristaltic action of the intestines through the splanchnic nerves, and the abdominal plexuses.

The effects of diseased states of the spinal cord also afford a support, which is more to be relied upon than the previous experiments, to the opinion that the motor and sensitive fibres of the sympathetic are implanted in the spinal cord. When there has been extensive lesion of the cord, from injury or disease, the intestinal canal is always affected to a degree proportional to the extent of the lesion; and this affection shows itself in the torpor of the intestines, and the readiness with which they become distended by flatus, giving rise to the tympanitic condition of abdomen, which so generally attends disease or injury of the spinal cord.

It had long been thought that the sympathetic nerve plays an important part in the sympathies of the body. Our improved knowledge of the anatomical distribution of the nerves, and of their physiological anatomy, and of their endowments, clearly shows that the phenomena of sympathy are explicable by the known laws of action of the great nervous centres, and that the sympathetic nerve can take no more prominent part in it than any other nerve; the extent to which it or any other nerve may be engaged in the play of such sympathies being proportioned directly to the extent of its central as well as its peripheral connections.

It would be more consistent, therefore, with a scientific nomenclature to discard the term *Sympathetic* as applied to this nerve; the old name *Intercostal* would, in some respects, be preferable. There is, however, great difficulty in finding a name which would adequately

express its constitution and offices, which may be summed follows.

1. In its constitution it is compound, consisting of tubular and of gelatinous fibres.

2. In its offices, it is a motor nerve to many of the internal of the body, the heart and the intestinal canal especially; it a sensitive nerve to these parts; and it presides over the act the blood-vessels of these as well as of other parts where it tributed, as of the head and neck, and likewise of all the pr glands of the body.

On the Sympathetic nerve, consult Cruveilhier, Anat. Descr.; Valentin, in S ring, Anat.; Longet, Syst. Nerveux; Lobstein, de nervi sympath. fabricâ, & entin de function. nerv. cerebr. et sympath.; Mr. Beck, paper in the Phil. T 1846; Müller's Physiology; Bidder und Volkmann, die Selbständigkeit des thischen Nervensystems, Leipzig, 1842; Kölliker, die Selbständigkeit und A keit des sympathischen Nervensystems, Zürich, 1844; Purkinje, in Müller's for 1845, and translated in the Lond. Med. Gazette, vol. xxxvi., has described ramifications which he considers to belong to the sympathetic, in the pi dura mater, serous membranes, and other parts. Mr. Rainey also describ Chir. Trans. vol. xxix.) the arachnoid and subarachnoid tissue as consistin entirely of such nerves, a view which it is impossible for us to adopt. M remains to be cleared up as regards the anatomical history of the sympathet in particular parts. Monographs upon the nerves of the heart, of the stom intestines, &c., are great desiderata, founded on careful and minute dissec experienced anatomists, with the aid of the microscope. Further researches wise required on its distribution to the extremities.

CHAPTER XXII.

GENERAL VIEW OF THE FUNCTION OF DIGESTION.—OF THE MINOR TIONS WHICH CONTRIBUTE TO IT.—OF FOOD.—ITS QUALITY QUANTITY.

Having discusesd the great animal functions of Locomoti Innervation, we now commence the consideration of those c functions which are more directly concerned in maintaining t trition, and, consequently, the life of the individual.

Of the nutritive processes, the function of Digestion is clea most prominent and most important, inasmuch as it is that tl which the animal is enabled to receive the aliment, and to pre for being assimilated to, and appropriated by, the various textu organs of the body.

Under the general expression, "function of Digestion," m comprehended several minor processes, all tending to the same namely, the reduction of the food for the nourishment of the The number of these subordinate processes varies with the de complication of the digestive function, which is obviously influ

by the complicated nature of the animal's body, and by the part which it has to play in the economy of the world.

Taking the digestive process, in its highest degree of complexity in man and the mammalia, we find that there is provision, first, for the *prehension* of the food; secondly, for its mechanical division and comminution (*mastication*), and for its admixture with a peculiar fluid (*insalivation*); thirdly, for the conveyance of the food into that portion of the alimentary canal in which its principal chemical changes are to take place (*deglutition*); fourthly, for the solution and reduction of the food preparatory to its being brought into a condition favourable to absorption (*chymification*); fifthly, for the separation of a material which shall contain in a condensed form the chief nutritive principles of the food, and which is easily absorbed into the blood (*chylification*); and lastly, for the removal of such portions of the food as have not been absorbed into the system during its passage along the alimentary canal (*defæcation*).

In examining the digestive process in the inferior classes of animals, various modifications are found to take place in it, according to peculiarities in the habits of the animals, or in the nature of their food; and also according to the complexity of organization exhibited by them.

In *Mammalia*, modifications occur in the masticatory process; the vegetable feeder requiring a more complicated dental apparatus; the carnivora being provided with teeth of a simpler construction, but more fitted for seizing and lacerating the prey. In others, again, the teeth are adapted to feed on insects, the Insectivora; in others, the Rodentia, certain teeth are constructed for gnawing dry and resisting substances; whilst in some of the whales, there are no teeth at all, strictly speaking, but only an apparatus which will allow of retaining the finer kinds of food in their passage into the mouth of the animal. The other sub-processes of digestion are carried on very much upon the same plan as in the human subject, with only such variations as the habits of life of the animals may render necessary. Thus, in a large tribe of Mammals, the *Ruminantia*, the food is macerated in a complex stomach, prior to, as well as after, it has been subjected to a more complete mastication than is employed in any other animals. In these, as well as in all vegetable feeders, the intestinal canal is very long and capacious, and the cœcum of great size. In the Carnivora the stomach is simple, and the intestines short and narrow.

In *Birds* there are no teeth; and mastication, properly so called, is effected in the stomach, a portion of which (the gizzard) acquires a great increase of muscular power, and is lined by a dense cuticle, and thus becomes a powerful organ for triturating the food, the bird swallowing pieces of flint or other hard substances to aid the mechanical reduction. Insalivation is but slightly developed, excepting in the woodpecker, where very large salivary glands pour out a considerable quantity of saliva to aid the bird in picking the dry bark and wood of trees. In some birds, however, a dilated portion of the œsophagus (the *crop*) gives lodgment to the food for a time, and pours out from its mucous membrane a fluid which probably performs an office similar to that of the saliva, and which at least must serve to moisten the food before it passes further along the digestive tube. Chymification and chylification are essentially the same as in Mammals; and there are likewise similar differences as regards the length and development of the intestinal tube in carnivorous and herbivorous birds. In *Reptiles* the digestive process is, on the whole, simpler than in the preceding classes; but there are the same sub-processes, the alimentary canal being of a simple construction. The dental apparatus varies according to the mode of life of the reptile, (the fangs of serpents having evident reference to the predatory habits of that class of reptiles,) excepting so far as the beak may be regarded as a substitute; and in some, as the *chelonia*, it is entirely absent. In *Fishes* there are well developed teeth of various forms, and often very numerous, with a simple stomach and intestine, but no salivary apparatus.

In the *higher Invertebrata* the digestive process is carried on upon the same plan as in the vertebrata. In the *Cephalopods*, there are powerful instruments of prehension in the arms or tentacles which surround the animal's mouth and head. These

animals enjoy a certain power of mastication by teeth, and some of them have a gizzard. All the *Mollusca* have a large liver; but other glandular organs connected with the intestinal canal, and more or less subservient to digestion, namely, the pancreas and spleen, are absent. The stomach and intestinal tube are very much as in the vertebrata. The *articulata* have also a digestive system like that in the vertebrate classes, but the liver is small, and developed in the rudimentary form of cœcal tubes opening into the intestine.

In the *lower Invertebrata* digestion becomes very simple. The intestine and stomach become much reduced in size; and in some the digestive apparatus consists only of a simple bag, as in the fresh water polyps, having the same orifice of entrance and exit; or, of a series of sacs or bags, with certain tubular appendages, as in the Asterias, and in the Actinia; in these latter animals one orifice answers equally for the introduction of the food, and for the discharge of the superfluous matters. In Medusæ, the oral aperture leads to a capacious cavity or stomach, from which certain canals carry the nutritious material into the different parts of the body; these canals being probably analogous to the circulating systems of the higher animals. In some polyps, the *Bryozoa*, as shown by Dr. Arthur Farre, a portion of the stomach exhibits great muscular power, and seems to perform the function of a gizzard.

We shall find it convenient to examine the function of digestion by tracing it through the various stages, as above enumerated, describing the mechanism of each of the subordinate processes, and the change which each of them is capable of effecting in the food.

Before we enter upon these points, we must make some remarks upon the nature and quantity of the food suitable for the nourishment of man.

It has been already remarked at a former page (p. 59), that no food is suitable for the support of the human frame in a healthy state, but that which contains the great staminal principles, which are the chief constituents of the body. And the same remark applies with equal force to the carnivorous, and probably to the herbivorous classes of animals.

The food of the lower animals varies to a remarkable extent. But nearly, if not entirely, throughout the series, organized matter, either vegetable or animal, forms the proper nutrient material. It is probable that some of the lowest creatures enjoy the power of assimilating inorganic matter, and thus become the instruments of making the inorganic substances indirectly subservient to the nutrition of the higher animals.

The elements of nutrition for man, and the higher classes of animals, exist in the vegetable as well as in the animal kingdom. But some animals are so constituted, that, in a state of nature, they subsist only on the flesh of other animals; while others live only upon vegetable food. Some carnivorous animals, however, may, in a state of domestication, be brought to eat vegetable food; but it rarely, if ever, happens that the herbivora can be taught to eat animal food. Man is, by nature, a truly omnivorous animal; and a certain admixture of animal and vegetable food is known, by experience, to be that which is most conducive to his healthy nourishment.

The classification of food which Dr. Prout has adopted, appears to us to be eminently practical—and on that account we recommend it to the attention of our readers. As water enters so largely into the constitution of the body, being essential to the integrity and to the vital action of the solids, and as it forms the principal part of the

ood, it is necessary that all animals should be supplied with liquid ed in some shape. Accordingly, water, either alone or holding portant nutrient elements in suspension or solution, forms part of food of all animals—the *aqueous* group of alimentary materials f Prout.

A large number of substances derived from the vegetable kingdom, stitute the *saccharine* group of Dr. Prout. These are character- ed by being composed of carbon, united to hydrogen and oxygen, the proportions in which these latter elements form water; the pro- rtion of the carbon varying from 30 to 50 per cent. (See *Prout's pers in the Phil. Trans.*) This group comprehends sugars, starch, ms, vinegar. These substances are contained in vegetables of rious kinds, sometimes forming their principal constituent, and at her times combined with other nutrient principles.

The *oily* or *oleaginous* group of alimentary substances comprehends l those substances whose composition consists of olefiant gas and ter. It includes the various fats and oils, as well as alcohol. It sembles in ultimate constitution the saccharine group; the propor- n of carbon in the various substances contained in it varying from to 80 per cent.

A fourth group, the *albuminous*, is made up of all those substances hich contain nitrogen—such as fibrine, gelatine, albumen, caseine, getable gluten. All the materials which make up this group are rived generally from the animal kingdom, with the exception of the t, which is contained in great abundance in wheat; similar, if not ntical, principles exist in vegetables. Wheat, indeed, consists of o substances—one referable to the saccharine group, the other to albuminous, the former consisting of starch, the latter of gluten. is fact was recognized more than a century ago (an. 1742) by Bec- ia, who assigned the glutinous portion to the nourishment of the rogenous tissues of the body. (*Dr. Thomson, Med. Chir. Trans.*, 46.)

In milk we find a natural combination of all the various substances ployed for nutrition—and it is a fact of the highest interest that product of animal secretion, elaborated for the nourishment of the ung, should contain one or more substances for each of the above- ned groups of alimentary materials.

Thus, milk consists of water, sugar, oily matters (butter), caseine; l wheat, a substance of almost universal application for food, ex- its an analogous union of starch, the representative of the saccha- e group—and of gluten, representing the albuminous.

It must be borne in mind that the albuminous aliments are distin- ished from those of other groups by their containing nitrogen. Food this kind is especially fitted to be directly assimilated to muscle, rve, and the other animal tissues, into the composition of which rogen enters largely. These aliments contribute directly to the mation of the blood, from which the tissues attract the principles st proper for their nourishment.

The non-nitrogenous aliments are obviously fitted to nourish those tures which do not contain nitrogen, as the fat; or to supply those

secretions in which carbon abounds, as the bile. Moreover, they furnish those large supplies of carbon which, we are warranted in supposing, the animal economy stands greatly in need of, not only from the great amount of that element which is to be found in all the tissues, but also from the large excretion of carbonic acid which is constantly taking place from the respiratory and other surfaces of the animal body. The formation of carbonic acid in the economy by the union of carbon and oxygen is, no doubt, the immediate cause of the generation of animal heat, and thus the supply of carbon in the food becomes of great importance to the maintenance of the proper temperature of animals.

From the natural subdivision of the food of man into two classes—one, consisting of the nitrogenized matters, well adapted by their constitution for the formation of blood, and the other, the non-nitrogenized substances, serving to supply a large amount of carbon—Liebig proposes to name the former *the plastic elements of nutrition*, and the latter *elements of respiration*.

To the first term we see no objection—but the use of any term which would imply that respiration must be, as it were, fed directly through the digestive process, appears to us scarcely consistent with the real facts of the case. The respiratory process is partly a process of supply, and partly one of depuration. It supplies oxygen, and it assists in the removal of effete matters in the shape of carbonic acid. The effete particles of the tissues would probably supply sufficient carbonic acid to effect the attraction of the required amount of oxygen—but as the supply of oxygen has the ulterior object of generating a due amount of heat, there will be required for this purpose a larger quantity of carbon than can be obtained merely from the destructive assimilation of the tissues (to use Dr. Prout's expression). Hence, for this purpose, a special supply of carbonaceous material must be furnished to the blood—and this is derived from the non-azotized alimentary substances. We prefer, then, the terms lately proposed by Dr. R. D. Thomson, namely, *calorifacient* for the non-nitrogenized substances, *nutritive* for the azotized matters.

It is proper to notice that azotized matters may be calorifacient, inasmuch as they contain a large quantity of carbon; and it is known that large tribes of men live on animal food alone. A large number of North American Indians, according to Cattlin, live almost exclusively on the flesh of the buffalo, the only non-azotized food which they obtain being the fat belonging to it.

In determining the nature of the diet to be furnished, in order to preserve man in a healthy state, care must be taken to provide for the calorific as well as the nutrient function; and hence the admixture of a certain quantity of non-azotized food is needed for the former function. In the cold northern climates the natives instinctively feed on fat and oily food, which contains a large per centage of carbon; while the natives of the warm south feed on fruits, which, as Liebig says, contain no more than twelve per cent. of carbon. Milk, the food of the young, in whom the production of heat ought to be most active, contains, according to Dr. Thomson, two parts of calorifa-

ent for one of nutritive matter. Eggs also contain nutritive matter a concentrated form, consisting chiefly of pure albumen, to which considerable quantity of calorifacient matter is added in the oleaginous yolk. The accumulation of these substances, as a natural provision for the nourishment of the young, whilst yet under the sole guidance of the purest instinct, or, as in the egg, where the nutrient matter is directly absorbed by the tissues of the embryo, affords the best indication that a compound food, consisting of such elements, is necessary for perfect nutrition at this period of life. As age advances, or the generation of animal heat becomes less active, the quantity of calorifacient food required is less, and that of the purely nutrient food more.

Experience justifies the conclusion to which our reasoning on these points leads, namely, that in the temperate climates the proper nutrient materials for infancy and childhood are milk, saccharine and amylaceous substances, the latter being combined with gluten; and that to these must be added a certain amount of gelatine, albumen, and fibrine, when the growth of the child and the more active play of its nervous and muscular systems call for a further supply of nitrogenized food. In adult life, azotized substances are needed, as the principal portion of the diet, to supply the waste which mental and bodily exertion gives rise to.

It must be confessed, however, that the views which theory suggests upon this subject are not such as would enable us with benefit, or even with safety, to determine the suitable diet for man. We learn much from instinct and more from experience, which we could never have gathered from *à priori* reasoning. Thus the importance of the admixture of vegetable with animal food could never have been determined without the aid of the experience afforded by the melancholy instances of disease generated by the privation of the former kind of aliment. Scurvy, as it is now well known, is frequently due to the want of a proper supply of fresh vegetable food; and it may be quickly and effectually cured by supplying this want. Again, it cannot be the deficiency of any of the staminal principles which gives rise to scurvy, because these exist in abundance in the animal food; and scurvy, it must be remembered, will occur in the midst of plenty of this kind of food. The disease is due to the deficiency of some unknown material necessary to health, which the vegetable kingdom alone can supply; and which, apparently, is most readily obtained from citric acid, lemon or lime-juice, or vegetables containing citric acid in good quantity, as the potatoe.

Nevertheless, the results of investigations as to the influence of particular kinds of diet in modifying nutrition, are strongly confirmatory of the views expressed above. Diet may be insufficient, either from its being given in too small quantity, or from its being defective in some principle, essential or incidental, necessary to the health of the blood—that fluid, upon the healthy condition of which the proper nourishment of the body depends. The effects of a diet scanty in quantity, although not objectionable in quality, are visible in the general emaciation, the wasting of all the tissues, and the consequent

debility. If dissolution be slow, the great non-nitrogenized material of the body, fat, is employed to supply the animal heat, as is strikingly seen in hybernating animals. Specific effects follow the absence of certain elements of the food, even although the absolute quantity of it be abundant. If nitrogen be deficient in quantity, or altogether absent, the imperfect nutrition shows itself in the formation of ulcerations of particular textures. Those tissues suffer most in which there is but little inherent activity of nutrition, or which are exposed to the contact of vitiated secretions. In Magendie's well-known experiments of feeding dogs upon sugar and water, the cornea of the eye ulcerated, and destruction of the organ ensued upon the consequent evacuation of the humors. Similar cases now and then occur in the human subject from the supplies of nourishment being inadequate. Ulcers are very apt to show themselves on the mucous membrane of the alimentary canal; they will form in the mouth or in the intestine. These signs may be accompanied with a more or less scorbutic state, as shown in spongy gums, subcutaneous ecchymoses, &c., according to the extent to which the blood has suffered; they may occur, too, where there is abundance of fat, although wasting of muscles. If the supply of non-nitrogenous food be large, fat will be formed. When Magendie fed dogs exclusively on fat, there were ulceration of the cornea and wasting of muscle, but the tissues were infiltrated with fat. The case of the ill-fated Dr. Stark illustrated the effects of the long continuance of a diet deficient in nitrogen. This physician, with ill-directed zeal, dieted himself for four months chiefly on non-azotized food, water, butter, oil, sugar, taking only bread in small quantity, and meat or fish occasionally as azotized food. In a short time, well-marked scorbutic symptoms showed themselves without any diminution in the fat of his body; but subsequently diarrhœa, the result of ulceration of the intestinal mucous membrane, came on, and terminated his career.

Of the Quantity of Food necessary for Health.—The proper quantity of food necessary for the support of general nutrition in a healthy state can only be determined by the results of observation and experiment; and the best mode of gaining information on this point is to consult the diet tables of various public institutions, in which due attention is paid to the health of the inmates, or to ascertain the allowances which are found sufficient for the army and navy. Each seaman in the British naval service, is allowed from 31 to 35¼ ounces of dry nutritious food daily, of which 26 ounces are vegetable and the rest animal, the latter consisting of nine ounces of salt meat or 4½ of fresh. Sugar and cocoa are also given. The soldier is allowed a pound of bread and three quarters of a pound of meat. In most of the London hospitals, full diet, which is given to convalescent patients who need a liberal diet, consists generally of half a pound of meat, with from 12 to 14 ounces of bread, half a pound of potatoes, a pint of milk, and sometimes beer or porter, a pint of the former or half a pint of the latter. The former dietary is destined for men who must be in readiness for the most active athletic exercises, requiring not only great muscular strength, but also considerable power

of enduring fatigue. The latter is intended to recruit the powers of those who have been suffering from disease. If, now, we compare with these a dietary which has been found sufficient for the support of health in a state of more or less confinement, with a moderate amount of daily labour, we may fairly infer that the proper allowance for persons not engaged in actual manual labour lies between these extremes. In the union workhouses of England, able-bodied men obtain about 25 ounces of solid food daily, of which the quantity of meat does not exceed 5 or 6 ounces. In prisons it has been found necessary to give a certain amount of animal food to prisoners who are subject to hard labour. Each of such prisoners, if confined for a term exceeding three months, and kept at hard labour, has a daily allowance of about 36 ounces of food, of which meat constitutes only a very small portion, namely, about 16 ounces in the week, four ounces on each of four days in the week. The prisoner has obviously the advantage of the poor man, whose only crime is poverty. But there is doubtless sufficient justification for this, in the fact that the labour of the prison, and the mental depression which long-continued restraint and confinement induce, render a greater amount of nutriment necessary than the indigent would require who seek in the workhouse a shelter from absolute want.

It is plain, then, that a daily amount of food, varying in quantity between 35 and 25 ounces, is sufficient to maintain health; but of this a fourth or a fifth ought to be animal food, especially when bodily exertion is being used. An amount greater than this is prejudicial, as affording material for the formation of new compounds, which serve only as *materies morbi* that may contaminate various tissues or organs, and impair their physical and vital properties. A lesser quantity, on the other hand, makes a poor blood, weakens the cohesive power of its elements as well as the attractive force of the tissues; and thus, in this latter case, *materies morbi* may be generated from the decomposition or the imperfect composition of the elements of the blood, and the tissues will suffer partly from not appropriating a sufficient quantity of the nutritious elements contained in the blood, and partly from the inferior quality of those elements themselves, which are probably also contaminated by some new compound.

In proportion as our knowledge of pathology, or the intimate nature of disease, extends, we become better able to treat disease with advantage on physiological principles; and it must be evident to all, who fairly consider the subject, that nothing is more important than to determine the proper diet suitable to particular maladies. We must not content ourselves merely with starving or feeding a diseased person; but we must give him that kind of food (whether in large or small quantity) which his digestive organs can most readily assimilate, and which will not serve as pabulum to the morbid matter which is apt to be generated in his system. It is in diseases of the kidneys and liver that the most manifest good is derived from a well directed dietetic system. In diabetes it has long been determined that a diet of animal food, with abstinence from sugar, and substances, such as starch, capable of being converted into sugar, is productive of excel-

lent results. In diseases of the liver, more is to be gained by close attention to the quantity of the food than to the quality; at the same time that it must be borne in mind that a nitrogenized diet is more suitable than one abounding in carbon, which would throw upon that organ a work of elimination greater than it may be able to bear. In the rheumatic and gouty diatheses attention to diet is the main resource to counteract the tendency to generate the morbid agents which severally produce those states of constitution.

When there is a tendency to the accumulation of fat, a nitrogenized diet in regulated quantity is the most suitable to obviate it. When more carbon enters the system than is required for the calorifacient and respiratory functions, or for the nourishment of tissues, it will accumulate as fat: and it is only to be removed by the free admission of oxygen to consume it, care being taken at the same time not to favour further accumulation by the supply of too much food, especially of the non-azotized kind. The practice of trainers furnishes a useful commentary on this point, and may be imitated by many who suffer from dyspepsia. The following account of the system pursued in training was communicated to Sir John Sinclair by Mr. Jackson:—

"The diet is simple—animal food alone; and it is recommended to take very little salt and some vinegar with the food, which prevents thirst, and is good to promote leanness. Vegetables are never given, as turnips, carrots, and potatoes; but bread is allowed, only it must be stale. They breakfast upon meat about eight o'clock, and dine at two. Suppers are not recommended, but they may take a biscuit and a little cold meat about eight o'clock, two hours before they go to bed. It is reckoned much against a man's wind to go to bed with a full stomach, and they in general take a walk after supper. Some people will have tea; but it is not recommended, nor is it strengthening, and no liquor is given warm. Full and substantial meals are given at breakfast and dinner; beef and mutton are best. It is contended that there is more nourishment in the lean of meat than the fat, which is fully proved by experiment, fat, being of a greasy nature, causes bile, and palls the stomach: the lean of fat meat is best. Veal and lamb are never given, nor is pork. The legs of fowls, being sinewy, are much approved of. The yolk of a raw egg is reckoned the best thing in a morning, and is supposed to prevent bilious complaints. Beefsteaks are reckoned very good, and rather underdone than otherwise, as all meat in general is; and it is better to have the meat broiled than roasted or boiled, by which nutriment is lost. No fish whatever is allowed, because it is reckoned watery, and not to be compared with meat in point of nutriment. The fat of meat is never given, but the lean of the best meat. No butter nor cheese on any account; cheese is indigestible. Meat must be dressed as plain as possible without seasoning of any kind. Men will live longer on beef, without change, than on any other kind of animal food, but mutton is reckoned most easily digested. The meat must always be fresh, and never salted. No quantity of meat is fixed; it depends upon the constitution and appetite. Little men will eat as much as large men, and very frequently more. Pies and puddings are never

ven, nor any kind of pastry; as to hard dumplings, people may as ell take earthenware into their stomachs."

This system, it must be remembered, is combined with one of tive and even severe exercise.

The periods for taking food, and the quantity to be taken, are der the natural guidance of certain sensations, which we call Hunger, Thirst, and Satiety.

Hunger.—The immediate cause of hunger cannot be explained. t is probably a sensation dependent on a peculiar condition of the ucous membrane of the stomach, which certain states of disease ay blunt or may increase to an inconvenient extent, as in diabetes. he nerve which is instrumental in this sensation is probably the agus nerve by its gastric branches, but there is no reason for denyig to the sympathetic nerves, distributed to the stomach, some share this phenomenon. The experiments of Brachet and Dr. John eid, relative to the influence of the nerves on hunger, lead to no tisfactory conclusion, because of the difficulty of interpreting the nsations of dumb animals, and the probability that appetite would e destroyed or impaired after any serious operation, even although he injured nerve had nothing to do with the stomach. The sensations caused by extreme hunger would indicate that some further hange was taking place in the wall of the stomach. A peculiar nse of sinking referable to the gastric region, general faintness, ecretion of gas into the stomach, and sometimes actual pain, accompany this state.

When these sensations are not relieved by their appropriate stimulus, food, the effects of fasting begin to show themselves. The body ow feeds upon itself—in other words, the process of destructive ssimilation is the only source from whence the blood derives its aterials of supply. All the tissues show the effects of impaired utrition in the deficient manifestation of their vital powers—the nimal loses weight, and, according to Chossat, this loss is most apid the few days immediately preceding death. The tissue which astes most is fat, and those which lose least are the osseous tissue nd the nervous. There is also great loss of heat; Chossat states at the daily fall was half a degree of Fahrenheit; but on the last ay it fell much more rapidly, reducing the temperature to 77°. The omach is much contracted, and its mucous membrane thrown into ick folds or rugæ. The gall bladder is generally full to distention, e intestines are contracted like the stomach; according to Collard e Martigny, the lymphatics become full in the first ten days of fasting, but afterwards their contents decrease considerably. The respiratory movements become slow, and the pulse falls considerably in equency. The urine becomes scanty, and all the parenchymatous rgans are remarkable for their paleness. Furious delirium frequently anifests itself, when the loss of strength becomes considerable. A imilar delirium sometimes ensues where too rigid an abstinence has een observed in the treatment of disease.

The period at which death occurs from protracted abstinence aries greatly; young animals die sooner than old ones. Dogs live

34

from twenty-five to thirty-six days. In man, total privation is borne above a week. By the aid of a little drink, given now and then, life may be prolonged considerably, and instances are recorded where it continued for eighteen or nineteen days, or even for ... days. Dr. Willan saw a gentleman who voluntarily abstained from everything but water, flavored with orange juice, for sixty days, and then died. Medical men, however, should exercise much circumspection in cases of professed abstinence, numerous impostures having been practised on this subject.

Thirst results from a peculiar state of the mucous membrane of the digestive tube, but more especially of the mucous membrane of the mouth and fauces, caused by the imperfect supply of liquid. A sense of clamminess in the mouth, pharynx, and even down the œsophagus, accompanies extreme thirst. The thirst in fevers is probably due to the state of the blood and the consequent change in the secretions. Injecting thin fluids, as water, into the blood, relieves the thirst of poisoned animals, as found by Dupuytren and Orfila. Injecting liquids into the stomach relieves thirst, as was found in a case where the œsophagus had been wounded.

On the subjects of this chapter the reader may be referred to Dr. Prout's papers and works—Dr. Paris on Diet—Dr. Pereira's work on the same subject—Dr. Stark's works—Dr. Latham's account of the disease prevalent at the Penitentiary, 18..—Dr. Budd's lectures on diseases produced by insufficient nourishment, Med. Gazette—Sir John Sinclair's Code of Health, in which many interesting tracts relating to diet and regimen have been preserved—Tiedemann, Physiologie, Band. iii.—Liebig's Animal Chemistry—Dr. R. D. Thomson on Food.

CHAPTER XXIII.

OF DIGESTION.—PREPARATORY PROCESSES; VIZ. PREHENSION, MASTICATION, INSALIVATION, DEGLUTITION: THE ANATOMY OF THE ORGANS CONCERNED IN THESE PROCESSES.*

In the present chapter we shall consider the preliminary stages in the function of digestion, under which head may be included all those which precede the entrance of the food into the stomach.

* In entering on a consideration of the alimentary processes, a few words may be conveniently introduced regarding the general anatomy of the *mucous system*, a term under which we include the skin, mucous membranes, and true glands, all of which are continuous with one another, and composed essentially of similar parts. The skin and the glands pertaining to it, as well as several parts of the mucous membranes, have been already minutely described in treating of the organs of sense. It only remains, therefore, to speak of the great internal mucous tracts, with their associated glands.

The *alimentary mucous membrane* commences at the lips, and lines the passages traversed by the food from the mouth to the anus. The principal glands whose ducts open upon it, are the mucous and salivary glands, the pancreas, and the liver. Besides these, its thickness is made up, in the stomach and small intestines, of an in-

nsion, or the taking of food into the mouth, little needs be performed chiefly by the hand, that wonderful instrument wer instincts as well as of his higher attributes. The lips , as well as the anterior teeth, and the tongue, are also n this function.

are endowed with great sensibility, derived from the su- nferior maxillary divisions of the fifth pair of nerves, and with largely developed papillæ of touch, which receive

tubular offsets, vertically arranged, pouring their contents on its free rming *an involuted or compound membrane*, or a diffused or membranous *espiratory mucous membrane* begins at the nostrils, sends processes to he optic, and the auditory organs, and lines the air-passages to their numerous mucous glands occur in this tract. Lastly, the *genito-uri- membrane* commences at the genito-urinary orifices, lines the excretory ining to both functions, and is the essential constituent of the glands e female, however, there is an exception in the case of the ovaries, as ed in a subsequent page.

into all the recesses of the mucous system, and forming its chief bulk, *ed particles*, arranged as a layer, and developed in succession, in such the old ones disappear, while others advance from below. An *epithe-* culiar to the mucous system, but is met with also on serous membranes, lls of the blood and lymphatic vessels, as well as elsewhere; but it is here by its external position as regards other textures, so as to be ca- g from the body, or to be exposed to the contact of foreign substances. of this epithelium are very different in different parts, and may be di- y, columnar, glandular, and ciliated. The *scaly* variety is seen on the e alimentary tract as low as the stomach, as well as in the excretory enito-urinary tract. (See vol. i. pp. 404, 412, 437, &c.) The *columnar* s of rod-like particles, placed endwise, generally bulged near the cen- eus, and narrowest at the point of attachment. They are met with in s, on the intestinal villi, in the bile-ducts, and elsewhere. The *glandu-* ulky, its particles rather globular than flat or long, and found in all the eral secretions being essentially the contents or substance of the par- The *ciliated* particles are columnar or sub-globular in shape, but r free margin with cilia, as in the examples formerly figured, (vol. i. , p. 4.) They are found chiefly in the respiratory tract, and in parts of t of the female. The true scaly and glandular varieties of epithelium ted. See Cyclop. Anat., art. *Mucous Membrane.*

um rests for the most part on a layer of membrane, hence termed *base-* , which, in the best-marked examples, is distinctly homogeneous and it in some situations is finely fibrous, and not easily separable from l other tissues which lie below it. These two, the epithelium and the nbrane, may be regarded as the constituents of a *simple mucous mem-* the latter cannot be everywhere traced, for example, in the interior of ules. The office of the basement membrane seems to be in all cases epithelium, and to shut in or cover over those tissues which may be ternal to the elements of the simple mucous membrane. Professor lers that the basement membrane is covered with points, which he f nutrition, from which the development of the particles of epithelium we cannot accede to this view; first, because the best examples of brane display no such points; and, secondly, because such a suppo- ning to explain the successive growth of the particles.

which lie under the simple mucous membrane, as now sketched out, ue, blood, and lymphatic vessels, and nerves, and in some situations a ary tissue. These, in their several forms and proportions, greatly racters of the membrane, as it is presented to the naked eye, and con- to our common notions of the structure of the skin, mucous mem- ands. The areolar tissue forms the *cutis vera* of the skin, (vol. i. p. orresponding part of the great mucous tracts; while in glands it is ch smaller quantity. The blood-vessels and other textures are modi- ways, as will be hereafter noticed in detail.

an abundant supply of blood from the coronary arteries. Along their margin the skin becomes continuous with the mucous membrane of the digestive apparatus, which, within these parts, as well as over the rest of the mouth, the pharynx and œsophagus, as far as the stomach, has an epithelium of the scaly variety; this variety forming the most essential character of that subdivision of the digestive apparatus considered in this chapter. The lips are moved by about twenty muscles, and are capable of grasping and retaining the food placed within them, and of aiding in the subsequent motions which it is made to undergo in the mouth. Their employment in articulation will be spoken of in another place.

The lips and the tongue undergo a variety of modifications in the animal series, with reference to the function of prehension; among these may be enumerated the enlarged, pendulous, and very movable lips of the ruminants and solipeds, and of some monkeys. Man uses his lips in suction, as do the young of all mammalia, at the breast. Among fishes, the cyclostomatous group (as the lamprey) have a suction power of a similar kind, their circular mouth being surrounded and supported by a ring of cartilage, and furnished with appropriate muscles for producing adhesion to surfaces to which it is applied. In birds, the lips are modified so as to form the bill, which is always the prehensile organ in that class.

The tongue is used by man and animals in suction, somewhat as a piston, being drawn within the mouth so as to exhaust the anterior part of that cavity, and allow fluids to enter by the atmospheric pressure. The canine and feline races employ the tongue to lap fluids; the giraffe twines this organ around the leaves and branches of trees, and detaches them with force. The ant-eaters have a remarkably long tongue, covered with a slimy secretion; this they protrude, and upon it entrap their victims. The cameleon among reptiles, and the woodpecker among birds, have each a tongue enormously developed for the purposes of prehension: to these many other striking examples might be added.

The cavity of the mouth, in which *mastication* is conducted, is bounded, first, by the palate or roof of the mouth, a fixed and hard surface formed by parts of the upper maxillary and palate bones, supporting a dense fibrous structure, lined with closely adherent mucous membrane, and fitted to act as a resisting surface against which the tongue may press the food; and, secondly, by the cheeks, lips, and tongue, which, in reference to the present function, may be classed together as tactile and muscular organs, designed to *handle* the food while subjected within the mouth to the action of the teeth, and then to forward it into the pharynx. Projecting into the mouth, above and below, is an arched series of teeth, or grinding organs, firmly fixed by roots into the alveoli of the upper and lower maxillary bones. Those of the upper jaw are immovable, or only movable with the entire head; but those of the lower jaw are capable of upward, downward, backward, forward, and lateral motions, by means of the muscles of mastication acting on the bone in which they are implanted. By these motions of the lower teeth upon the upper, the food is comminuted. A more detailed description of some of the organs of mastication may now be given.

The *cheeks* form the outer wall of that part of the mouth which

side the teeth. Like the lips with which they are continuous, nsist of a muscular stratum interposed between the skin and :ous membrane of the mouth. They admit of distention and ssion, and form pouches which receive portions of food escap- side the teeth during mastication, and from which it is continu- ırned towards the inner cavity, to be submitted to the grinding This use of the cheek is well exemplified in cases of paralysis ıuccinator muscle, in which the food collects in the flaccid bag h this part is then reduced.

tongue is an important agent of mastication, and has been al- ›oken of as the seat of taste and of an exquisite sense of touch. ıe of the latter it receives accurate impressions of the tangible s of the food, and of its situation in the mouth; and by its ıobility it is constituted the main instrument by which the food :d within the mouth, so as to be effectually brought within the f the masticating organs. The tongue rests upon the hyoid ı which, and to the concavity of the lower jaw, it is fixed by scles. It lies within the curve of the teeth, and is covered on surface with mucous membrane, which has been before de- . The muscular fibres which compose this organ intersect one in an intricate manner in its interior, but they all appear to ıltimately at its dorsal surface, and to be there implanted, in ets or bundles, into the submucous stratum of dense areolar a good deal of fat being disseminated throughout, but espe- ı the intervals between the muscular bundles at their insertion. er to works on descriptive anatomy for the anatomy of these s. By their action the upper surface of the tongue may be onvex or hollow, or may be pressed forcibly against the roof mouth; the tip of the organ may be protruded or moved in ection, and to any recess within the cavity where food might and the whole organ may be lowered or drawn back. These actions are so performed as to exemplify, in the most perfect , the concert which has been already mentioned to occur be- nany muscular and sensitive parts.

he Teeth.—These, in the widest acceptation of the term, and ence to the whole animal scale, are hard organs situated on er surface of the digestive tube, fitted for comminuting the evious to its being acted on by the gastric juice. In the higher they are of an osseous nature and fixed to bone, though not ly. Among the invertebrata, the echini are remarkable for lcareous oral teeth, five in number. The mouth of the leech :d with three serrated teeth, worked by muscles, which saw ay into the skin. In some insects the gizzard is armed with complicated system of horny teeth. In the stomach of the ea is a cartilaginous framework, with projecting teeth, moved cles, and capable of very powerful masticatory actions. Among teropods, the bullæ have three stomach teeth; and others, as lysia, a great multitude, of large size and of different forms.

: osseous teeth are found only in three classes of vertebrata, ammalia, reptiles, and fishes. Some of these, however, are

without them, as, among mammalia, the American ant-eater, the manis, the echidna, the proper whales; among reptiles, the tortoises; and the sturgeon among fishes. The teeth of fishes are fixed not merely to the maxillary bones, but also to the palate and other bones, bounding the mouth and throat, and they are often extremely numerous. The bills of tortoises and birds perform some of the functions of teeth; but in those of the latter class which live on hard vegetable substances, the muscular gizzard, with its hard cuticle, and by the help of small angular stones which the instinct of the animals teaches them to swallow with the food, performs the functions of a masticatory apparatus. Among the mammalia, the teeth are few in number, and limited to a single row in each jaw.

Teeth may be classed according to their shape and the function they have to perform. Thus, the following varieties may be briefly enumerated:—The cutting or gnawing teeth of the rabbit or beaver, —the front teeth of man. The conical teeth of fishes for seizing and retaining prey—the canine teeth of the lion and dog. The hinder teeth of the carnivora, with several sharp elevations for tearing. The more complex crushing teeth of the insectivora, and of the frugivorous monkeys. Lastly, the true grinding teeth of granivorous and graminivorous animals.

Of the Human Teeth.—The teeth in the adult human subject are thirty-two in number, of which four are incisors, two canines, four bicuspids, and six large molars, in each jaw. Those of the upper jaw form the larger arch, so as to overlap those of the lower jaw in front, and to overhang them somewhat at the sides, when the mouth is closed. Each tooth has a *crown* or *body*, projecting above the gum, and a *root*, buried in the alveolus or socket; and the division between these is marked on the surface by a somewhat constricted line, termed the *neck*. Each tooth has also an internal *cavity*, containing a vascular and nervous pulp, and which is open only towards the root. Lastly, each tooth consists mainly of a peculiar modification of osseous structure, termed *dentine*, or *ivory*, which is coated over with calcareous *enamel* on the crown, and with a thin layer of true *bone* on the root. The position and shape of the several varieties of the human teeth are as follows:—

1. The *incisors*, or cutting teeth, are situated in front, (those of the upper jaw being the larger,) and present a single conical root of large size, and a vertical crown, bevelled behind so as to terminate in a sharp horizontal edge. These teeth are fitted for cutting the food. In herbivorous animals they crop the herbage, in rodents they are capable of gnawing even very hard substances.

2. The *canine* teeth come next to, and are larger than, the incisors, especially the root, which sinks deeply into the jaw, and renders the alveolar arch prominent by its size. This root is conical, and the crown more conical and less wedge-shaped than that of the incisors, being usually surmounted with a small pointed tubercle or cusp, whence they are termed *cuspidate*. In consequence of the small size of the lower incisors, the lower canines are nearer together than the upper, and fall within them when the mouth is closed. These teeth

in the canine, feline, and other carnivorous tribes, are largely developed, and more decidedly formed for lacerating and tearing the flesh of prey.

3. The *bicuspids*, or *false molars*, are not so large as the canines, which they succeed, but their crown presents two pyramidal eminences, as their name implies, and there is a tendency in their root to be double; this part being marked by a vertical groove, and its apex, sometimes bifid, being perforated by two apertures leading to the interior.

4. The *true molars*, or *multicuspidate* teeth, are placed most posteriorly, and are distinguished by their great size, the square form of their crown, surmounted by three, four, or five cusps, a distinct neck, and by their shorter, but more divided root, which presents from two to five branches, the inner the more divergent, and each perforated at its apex. The hindermost of these are the *wisdom teeth*. The false, and especially the true, molars are admirably adapted for grinding and pounding the food, under the influence of those powerful muscles by which the lower jaw is moved in a lateral direction while being forced against the upper. Though the least simple of the human teeth, these grinders are greatly surpassed in complexity of form and structure by the corresponding teeth of herbivorous animals, such as the ox, the horse, and the elephant.

The *internal structure of the teeth*, like that of bone, has been much illustrated by those modern microscopic investigations, which have introduced a new era in the sciences of anatomy and physiology. The researches on this subject, opened by Purkinje, Fraenkel, and Retzius, and subsequently pursued with more or less originality and extent by Müller, Schwann, Tomes, Nasmyth, and especially by Professor Owen, have confirmed the almost forgotten discoveries of Leeuwenhoek, and brought the whole subject of dental structure and development into clear and consistent light. We shall now give a short summary of the facts as they have appeared to our own minds, and refer, once for all, to the works quoted at the end of the present chapter, for information, as to the share each inquirer has had in the general and very satisfactory result.

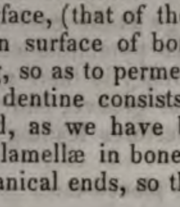
The three constituent substances, dentine or ivory, enamel, and tooth-bone or crusta petrosa, are found in all the higher and more perfect forms of teeth; and their several conditions in the range of animals have been greatly instrumental in leading to our present knowledge of them in the human teeth: our design, however, will allow us to speak of their character in the latter only, except in the way of illustration.

Taking a simple tooth as an example, (fig. 149,) we find the great bulk to consist of *dentine*, a term used by Mr. Owen to distinguish this substance from the rest, in preference to that of ivory or tooth-substance. The dentine gives the general form, size, and hardness to the tooth, both root and crown, and in its central part is the cavity containing the papillary substance or pulp, supplying the vessels and nerves of the organ.

Dentine is manifestly a modification of the osseous tissue. Like

bone, it may be seen in favorable specimens to present a finely granulated ultimate texture, and, like bone, it is perforated by a series of minute channels, opening on the one hand on a vascular surface, (that of the pulp-cavity, which corresponds with the Haversian surface of bone: p. 110,) and on the other sparingly branching, so as to permeate every portion of the tissue. The peculiarity of dentine consists chiefly in these internal channels of nutrition; and, as we have before shown the Haversian canals and systems of lamellæ in bone to be arranged in constant subservience to mechanical ends, so the corresponding parts in dentine, and especially those parts which answer to the lacunæ and canaliculi of bone, appear to derive their peculiar characters from the mechanical exigences of the case. The tooth having to sustain rude pressure on its crown, chiefly in a vertical direction, great density and compactness are requisite in its main constituent, and its internal vascular surface, which is small in proportion to the mass of dentine, is centrally placed, and receives its vessels and nerves at the deepest point, most remote from injury. As the vascular surface is small, and therefore at a great distance from a large proportion of the tissue, the interstitial channels of the dentine are capacious, especially towards the vascular surface, and comparatively direct in their course from it; and, instead of commencing minute as the canaliculi of bone do, and dilating at intervals, after a tortuous and irregular route, into hollow chambers, like the lacunæ of that texture, they are widest at their commencement in the pulp-cavity, retain throughout the simple tubular character, and are provided, for the most part, with proper walls, so that each tubule may be regarded as a hollow rod, the stem of which is of a harder and compacter nature than the intertubular substance through which it runs.

Fig. 149.

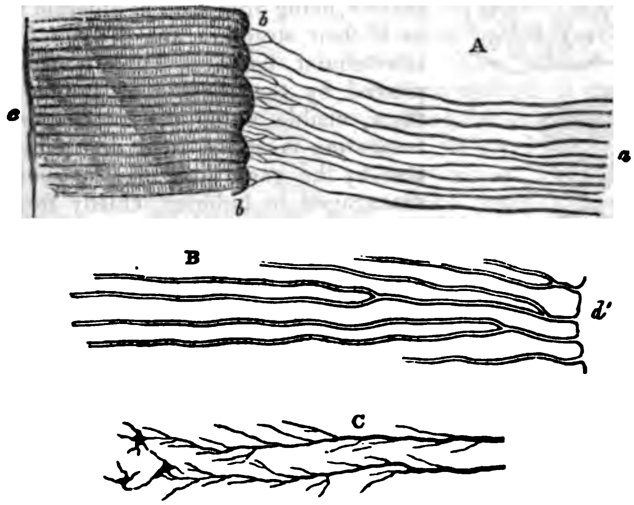


Vertical section of human incisor, showing the general arrangement of its constituent parts. The dentine and pulp-cavity, the enamel on the crown, and the bone on the fang, are seen. *a*. Neck of the tooth. Magnified 3 diameters.

The direction taken by the tubes is further interesting; for not only do they radiate on all sides from the vascular surface, as being the conduits of nutrition to the dentine, but they thus confer on every part of the tooth a greater power of resistance in an inward direction from the surface towards the centre, a power increased by the cylindrical shape of the pulp-cavity, and its tendency to an arched figure towards the crown. But it would appear that the beauty of the mechanical contrivance does not stop even here, for it has been observed that the tubes in many parts are doubly waved, like the Italic *f*, and that within these primary curves are comprised very numerous secondary meanderings; from which, as those of contiguous tubes have a lateral

correspondence, a certain elasticity, and a greater capacity of resisting external force, must accrue. The tubuli of the dentine now described, branch a few times dichotomously, and the branches retain for some distance the diameter of the trunk, this multiplication of their number enabling them to occupy the spaces which would be left by the radiation of unbranched tubes from a common centre. The tubuli are in some parts about their own width asunder, in others they run in

Fig. 150.



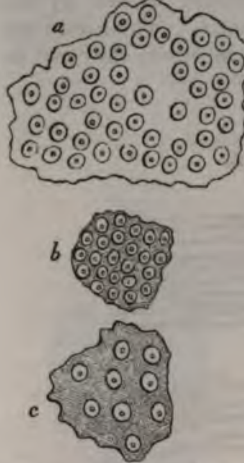
Sections of a human incisor, showing:—
A. Junction of dentine and enamel near the neck of the tooth. *a*. Tubes of the dentine, dividing and ending on *b b*, the cupped surface on which the enamel rods vertically rest. *e*. Free surface of the enamel. The enamel rods are crossed by transverse lines and also by oblique dark lines.
B. Bifurcation of the tubuli of the dentine, soon after their commencement on *d'*, the surface of the pulp-cavity.
C. Branching of the tubuli of the fang, and their termination in the small irregular lacunæ of the "granular layer."
In these longitudinal views of the tubuli, their cavities only, and not their walls, are visible.
Magnified 300 diameters.

mutual contact; and their compact proper wall is about as thick as their cavity is wide. Except near the pulp-cavity, they are, as it were, hairy with filamentary canaliculi, which diverge on all sides, and form innumerable junctions with one another; so that the tubuli, throughout most of the dentine, may be said to communicate with each other independently of the pulp-cavity, into which they all open. Towards the outer surface of the dentine, where it is incrusted on the crown with enamel and on the root with bone, the tubuli gradually taper, and finally terminate in diminutive canals, which open, some into small, irregular lacunæ (forming a layer on the root, termed by Mr. Tomes the granular layer), some into the lacunæ of the osseous investment of the fang, and others upon the surface on which the enamel rests. Occasionally the tubuli are dilated into true lacunæ, or form free arches of communication.

The following facts illustrate the foregoing account of the structure of dentine. The granularity of the ultimate tissue may be best seen

in specimens in course of development. On the surface of the pulp-cavity the orifices of the tubuli can be seen; and in transverse sections of the tubuli,* (fig. 151,) their proper walls, the width of their walls and calibre, and their distance apart, are all discernible. In broken fragments, especially if torn after the tooth has been softened in acid, the tubili may be observed to stand out from the surface, being broken off at different lengths, as if their structure was distinct from the intertubular tissue. Their hollowness is proved by the chasing of bubbles along them, visible under the microscope when turpentine is added to a dry section, and also by the gas which may be seen to be disengaged in bubbles, chiefly from their interior, when a section is similarly treated with acid. The latter experiment seems also to show that the parietes of the tubuli contain a denser deposit of earthy matter, and are consequently harder and more resisting than the intertubular tissue. We do not regard the tubuli as filled up by solid contents, but as possessing a truly hollow bore, designed to give passage to fluids.

Fig. 151.



Transverse sections of tubules of dentine, showing their cavities, walls, and the intertubular tissue.
a. Ordinary distance apart.
b. More crowded.
c. Another view.
Human molar.—Magn. 400 diam.

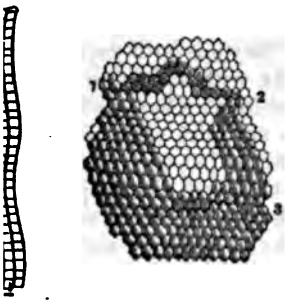
The *enamel*, investing the crown of the tooth, and forming that part which is exposed in the mouth to the contact of external substances, is harder and compacter than the dentine, and of peculiar structure, although formed, as will be afterwards shown, on the same general plan as the other portions of organized bodies. As its earthy constituents are in much larger proportion than in the dentine, (for they make up 98 instead of 72 out of 100 parts, according to Berzelius,) the enamel requires much less nutrient change, and its interstitial passages are very minute.

The enamel (fig. 150, A, and fig. 152) consists of a congeries of hexagonal rods, placed endwise side by side, so as to form a layer, of which the surfaces are formed by the ends of the rods, and the thickness is determined by their length. The deep surface rests on the dentine, which presents a number of minute depressions for the reception of the deep ends of the vertical rods, a number of which rest in each; and the superficial surface, though said to be at first coated with a thin film of osseous tissue, is afterwards rendered bare by the earliest movements of attrition in masticating the food, and then becomes the free surface of the crown of the tooth. The rods of enamel are about $\frac{1}{4500}$th of an inch in diameter, and they pursue a more or less meandering course, which must augment their power

* Mr. Topping, of York Place, New Road, mounts these and other objects very skilfully.

g external force. It is evident that their vertical position adapts them to sustain pressure, and withstand the effects rected upon the surface of the tooth; while, at the same nterstices or chinks intervening between them, principally ıgles of juxtaposition, are arranged in the most suitable permeation by the fluids derived from the subjacent dentinal tubuli. These tubuli, indeed, may be seen to communicate directly with the interstitial passages of the enamel. The enamel rods are further marked, at pretty close and regular intervals, by cross lines, which, however, are far from constant, and of doubtful nature: some suppose them explained by the process of development. The enamel rods are connected together by some remnant of the original organic matrix in which their earthy portion was at first deposited, and which is represented by the dark lines or chinks which appear to bound and isolate

Fig. 152.



section of the enamel, showing the ir cross lines.
he enamel, seen endwise.
) diameters. From Retzius.

As the rods are placed vertically on the surface of the 'hich is not an even one, they are not everywhere parallel, l length, but are truncated where they abut against each a hollow, and in such parts are most liable to decay. In s, however, near the dentine their vertical position seems ; they are curiously contorted, and neighboring series of 'ariously inclined, so as to lean against one another, while rods nearer the surface assume an upright and parallel The enamel on a vertical section further shows dark markng obliquely across the fibres (fig. 150, A), and not well l, and also larger cracks or fissures (fig. 149), often branched, rough a part or the whole of its thickness. As Mr. Owen d out, the enamel is the least constant of the dental tissues, nt in many fishes, in existing ophidian reptiles, and in the nd many cetacean mammalia.

th-bone or *cement* is disposed as a permanent thin layer of ssue on the roots of the teeth, and it also invests the enamel icate film on the first emergence of the tooth from the gum. ıt it is thickest towards the apex, and often lines the pulpthe dentine for a little way in. It contains sparingly the ıd canaliculi which characterize bone; and, when thick presents also the lamellæ of that structure. In general it small a quantity to require special Haversian canals; but s has shown, that, between the roots of the larger human tooth-bone is often in sufficient mass to be penetrated by a of that nature; and, in the teeth of many animals, the ce-

ment is as vascular as ordinary bone. The canaliculi of the tooth-bone are, for the most part, directed from the lacunæ towards the surface, where the vessels are spread out, but a few communicate with the peripheral branches of the tubuli of the dentine. It is through this osseous investment of the roots that the teeth adhere so firmly to the sockets in which they are implanted.

The *cavity* of the teeth, containing the pulp, is in the fully formed tooth the analogue of the Haversian canal of bone, by which the organs of nutrition and sensation find access to the internal surface. The blood-vessels of the pulp are branches of the internal maxillary, and the nerves of the fifth pair, and they are both extremely abundant, in proportion to the extent of surface with which they are in relation. The capacious capillaries form numerous arches, and the nerves likewise end in loops, (p. 204,) which are best seen in the young tooth. The white substance of the nerve-fibres has seemed to us to be often diminished or lost towards the convexity of the loops.

The *alveoli*, or sockets in which the teeth are set, are cavities in the border of the jaws, corresponding in shape and direction to the roots of the teeth, formed on the outer and the inner side by a firm, compact plate of bone, which bounds the alveolar arch in front and behind, and separated from one another by septa of less compact material. The surface of these cavities is spongy, being perforated by minute vessels, which pass across to the surface of the roots of the teeth, and which there form a plexus in the substance of a firm elastic tissue, which is the connecting medium between the socket and the root, and is usually regarded as a periosteum. Thus the surface of the root is supplied with blood, and the tooth is united to the jaw in a way which allows it to yield very slightly under pressure.

The alveolar arch is covered on the outside by the *gums*, a dense, elastic, peculiar tissue, adapted to sustain without injury the forcible contact of the hard portions of food, to which its vicinity to the grinding organs must expose it.

The *development of the teeth* may be described under two heads; first, that of the elementary tissues of the tooth, the dentine, the enamel, and the true bone; secondly, that of the dental series, which will include the order of appearance of the teeth of the temporary and permanent sets.

According to the most recent investigations of Arnold and Goodsir, the teeth are developments from the mucous membrane covering the dental arches, and not from the maxillary bones. They, therefore, would seem to correspond with the tegumentary appendages of animals, such as horns, nails, feathers, and not to be a portion of the true osseous system, or endo-skeleton of the vertebrata. The bills of birds are an obvious intermediate condition of the integument of the jaws.

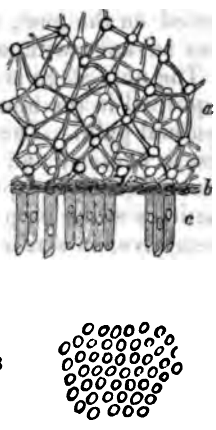
The teeth may be regarded as formed in the following manner. The first indication observed (according to the excellent observations of Mr. Goodsir, which we have, in most particulars, had an opportunity of verifying) is a groove at the border of the palate in the situation of the future teeth, which he terms the *primitive dental*

roove, and which is apparent in the fœtus of six weeks old. At the ɔttom of this groove there appear certain fine papillæ, which in-ease in size, and gradually assume the shape of the crowns of the ıture teeth, having the edge and cusps which are eventually to dis-nguish them. As the papillæ grow, the groove is converted into ıllicles for their reception, by the growth of septa between its bor-ers, that is, between the outer and inner alveolar processes, which ɔon begin to be ossified within the walls of the groove. Thus the ıllicles become alveoli lined by the periosteum of the jaw, such as it ; at this early period, and lodging a process of the mucous mem-rane of the gum, from the bottom of which springs up the papilla r germ of the future tooth. The summit of the papilla is at first isible in the mouth of the follicle; but ere it has assumed the figure f the tooth, the margins of the orifice enlarge and lap over, and nally meet and unite, so as to form a lid or operculum to the now losed cavity. Thus the epithelium of the lining membrane of the ıouth may be shown to form the lining of the follicle, and to be re-ected thence over the surface of the papilla.

Now, the tooth papilla must be regarded as homologous with, or nswering to, the tactile and hair papillæ of the skin, already described t a former page; and it would, therefore, be expected that its main art would consist of a peculiar sub-mucous tissue, covered by a ho-ıogeneous basement membrane, and surmounted by a tissue answer-ıg to the epithelium; and this seems actually the case. The sub-tance of the papilla is at first a congeries f granular nuclei, dispersed irregularly ırough a firm homogeneous sub-granu-ır matrix, or blastema, in which ves-els and nerves are by degrees deve-ɔped. This is bounded by a definite ansparent membrane, on which rests a eflection of the epithelium lining the ac, modified in structure, so as to pre-ent a series of columnar nucleated par-icles, the matrix of the future enamel. t would appear that the lining and re-lected layers of the epithelium become ılended together, and constitute but ne, which is more adherent to the sac han to the papilla, so that on opening he sac its wall generally seems to be nattached to the surface of the papilla, nd the latter to be limited by what we ıave regarded as the basement mem-ırane. Or, it may be that the epithelium eflected over the papilla disappears, eaving only that which lines the sac.

Fig. 153.

A



B

A. Vertical section of the enamel-pulp, with the columnar epithelium, which is to become the enamel. *a*. Pulp. *b*. Position of basement membrane. *c*. Columnar epithelium, some particles being detached.
B. Columnar epithelium seen endwise.
From a human fœtus of about five months. Magnified 200 diam.

Between the columnar epithelium hus lining the sac, and the surface of he alveolar cavity, that is, apparently in the wall of the sac itself, is

now found a thick, semi-transparent, pulpy tissue, which has been termed *the enamel-pulp*. It presents towards the pulp of the tooth (dentinal pulp) a series of elevations and depressions, precisely the reverse of those of the dentinal pulp on which they rest, and answering mutually to these, with only the columnar epithelium intervening. The structure of this thick pulpy tissue is very beautiful and peculiar, as is seen in the annexed woodcut (fig. 153, A, *a*). It consists of a mesh of short fibres, meeting in numberless points, and at each point of junction a transparent clear nucleus is visible.

It is elastic, spongy, loaded with fluid albumen, but destitute of vessels, and it seems perfectly distinct from that columnar structure which appears to be afterwards converted into the enamel.

In a vertical section of these parts, the enamel-pulp is seen covered with columnar epithelium, the *enamel-matrix* (fig 153, A, *c*, B), on the surface towards the dentinal or tooth-pulp; while, on the opposite surface, the blood-vessels of the membrane lining the alveolus are seen coming up to, and forming loops immediately under, the enamel-pulp, without penetrating it. It is further remarkable, that short tubes, filled with glandular epithelium, descend among these vessels from the enamel-pulp, and end by blind extremities. How these tubes, which are evidently glandular, can discharge their contents, it is difficult to understand, seeing they appear to open into the substance of the enamel-pulp: but their presence and precise situation we have ascertained to be as we have described them in the molar teeth of the nine months, human fœtus.

It is not impossible that the enamel-pulp may perform the mechanical office of protecting the soft and growing tooth from pressure directed on the gum, and of providing a space in which development may advance without restraint.

The next stage is that of ossification, and the earthy matter is first deposited in the homogeneous membrane forming the surface of the dentinal pulp. The most prominent portions of the crown are the first to harden; and the ossification proceeds inwards by the gradual conversion of the pulp into the dentine, or ivory. The nucleated particles of the pulp nearest the ossifying surface are found arranging themselves in series vertical to that surface; and it appears, that, in order to form these vertical series, they multiply by transverse division, much as those of bone cartilage are found to do. The earthy matters are then deposited in the indistinct cells surrounding the nuclei, so as to form the hard and dense walls of the dentinal tubes, as well as in the intercellular substance, so as to form the intertubular tissue of the perfect tooth. The cells unite endwise, and their nuclei elongate and coalesce in a manner to constitute the cavities of the tubes, and so as often to retain indications of this mode of origin in their permanent form. In all these processes a striking similarity to those noticed in the ossification of ordinary bone is to be traced. In proportion as the ossification proceeds inwards, so as to occupy the substance of the dentinal pulp, the vessels and nerves which had been developed in that structure recede, and finally come to occupy the cavity which remains in the interior of the tooth after its develop-

s been completed. The chief vascularity of the pulp is uni- ›und near the ossifying surface, whence it is evident that the ıaterials are supplied from that source. In the teeth of some in which the dentine is penetrated by many subordinate off- ı the central cavity, containing blood-vessels, these passages ın the progress of development, just as has been above de-

been already said that the reflexion of the original mucous ne of the follicle on to the papilla takes place at a line corre- g nearly to the *neck* of the future tooth, and that the original nswers to the crown or body of the tooth, and not to the root. er is a subsequent formation, and is laid down gradually after ı amount of ossification has already taken place in the crown, r the enamel has been calcified. It is formed and ossified by s precisely similar to that of the dentine of the crown, only protracted one, and during which the tooth is raised out of ınd bursts the containing gum. The lengthening of the fang ıg its ossification resembles closely that occurring at the junc- the shaft with the epiphyses of the long bones during their ment (p. 123).

:alcification of the enamel commences on the surface of the in contact with that primary osseous sheet formed from the ıt membrane of the dentinal pulp. On this primary layer are shallow cups, closely aggregated, answering to the ends of nel columns, and receiving them in a firmly cemented union, consolidation of the elementary cells proceeds. The enamel ı at a very early stage seem to consist only of a single series :ated particles, intervening between the dentine and the ena- p; but subsequently others are added on the surface towards nel-pulp. Those of the new row arrange themselves endwise ›thers, which they resemble in all respects, so that the enamel ts proper thickness rather by the superposition of particle on successively deposited, and by the subsequent calcification in its turn, than by the development of its parts by an inter- ıcrease; and thus it appears to differ from the dentinal pulp, esemble the epithelium, to which it is allied.

'rom that surface of the enamel-pulp which looks towards the ıat this successive development of new enamel columns pro- as they form, this tissue wastes; but it is not probable that › is converted into the columns, as the dentinal pulp is con- into dentine, because the anatomical characters of the pulp lissimilar from those of the columns. When first calcified, the rods are loosely aggregated, and easily separate from one an- nder pressure; but they gradually become so firmly consoli- y the advance of the calcifying process in their interstices, as e the finished enamel the most hard and indestructible of all lucts of organization.

development of the layer containing the ordinary lacunæ of ıd which, in the human teeth, covers the fang, and is continued way within the cavity of the root, does not seem to have been

so accurately studied as that of the dentine and enamel. But this is the less important, as it is in all probability essentially similar to that of bone, which is now pretty well understood. There can be little doubt that a membranous matrix, probably like that of the cranial bones, is laid down as the fang is developed, in which the usual steps of ossification proceed, the lacunæ and their canaliculi being, in our opinion, formed from the corpuscles of the temporary matrix. Mr. Nasmyth has described a prolongation of this layer over the entire crown of the tooth, outside the enamel. To understand the formation of such a layer, we must suppose it laid down in a matrix continuous with that which invests the fang, passing over the crown between the enamel-pulp and the wall of the sac inclusive of the lids. The crusta petrosa in the fissures between the enamel of the compound grinders of herbivorous animals must certainly be formed in this way.

When the ossification of the dentine is so far advanced that the tooth can sustain with impunity the pressure to which it is destined, and when the enamel is densely calcified, the *eruptive stage* occurs, in which the tooth makes its way through the gum. This is due to the same laws of development which govern the form and position of other organs. The gum over the sac is absorbed, and the crown of the tooth is forced upwards against it, chiefly by the increasing size of the fang below.

It may be stated, once for all, that, as the development of the teeth proceeds, so does that of the alveoli, or the bony sockets in which they are lodged; and that, by the time the teeth break through the gums, their walls are sufficiently strong, and embrace the necks of the teeth with firmness enough to furnish a solid basis of support. Their vascular canals are developed, and especially those which convey to each tooth its interior supply of vessels and nerves. The gums and alveoli are likewise provided with vessels which play their part in the development and subsequent nutrition of the organs. The nerves of the teeth are derived from the second and third divisions of the fifth pair.

Of the First and Second Dentitions.—As teeth are required before the jaw-bones have attained their full growth, and yet are organs incapable of enlarging *pari passu* with those bones, the young child is provided with a *temporary set*, commonly known as the milk-teeth, adapted to the size and form of its alveolar arches, and to the nature of the food consumed in early life. This set consists of twenty teeth —four incisors, two canines, and four molars in each jaw. They are formed in the manner already described: the papillæ of the anterior molars appearing first—between the sixth and seventh week of fœtal existence, according to Mr. Goodsir—followed by those of the canines, incisors, and posterior molars, about the eighth, ninth, and tenth weeks respectively. About the fourth month all these are in their saccular stage, the mouth of the follicles having closed; and there then appear behind the opercula, or lids of the follicles, small crescentic depressions of the mucous membrane, soon becoming closed cavities, called by the last-named author "*cavities of reserve*, to furnish delicate mucous membrane for the future formation of the pulps

sacs of the ten anterior permanent teeth" in each jaw. For two hree weeks longer the primitive dental groove behind the posterior c molar is furnishing the papilla of the first permanent true molar; , as this becomes gradually in its turn enclosed in a sac, a cavity iucous membrane is said, by Mr. Goodsir, to be left unobliterated veen its sac and the surface of the gum, which is the "cavity of rve" from which the development, first of the second true molar, , secondly, of the third or wisdom tooth, is afterwards to proceed. he temporary teeth usually make their way through the gum as ows, those of the lower jaw taking precedence: the four central sors about the seventh month after birth; the four lateral incisors i the seventh to the tenth; the anterior molars from the twelfth to fourteenth; the canines from the fourteenth to the twentieth; and posterior molars from the eighteenth to the thirty-sixth month. s whole period is called that of the first dentition, and is of it importance to the child, from the various sympathetic morbid s which universal experience attributes to the process of "cutting teeth;" but it would be beside our purpose to dilate in this place o interesting and prolific a theme. It may suffice to say, that, in opinion, the practice of lancing the gum over an advancing tooth ten unnecessarily and prematurely resorted to, when there is no lence, from its tense or inflamed state, that it is offering any un- obstacle to the progress of the organ beneath.

he ossification of the permanent teeth commences a little before i with that of the anterior molars, and in the course of the first, ond, and third years it proceeds gradually in the incisors, the ca- s, and bicuspids. Their position in the jaw, meanwhile, has been ergoing change. The cavities of reserve, from which the devel- ent of the ten anterior permanent molars proceeds, are, at first, ed between the milk sacs and the gum; but as the papillæ are form- as already explained, they recede behind, or to the inner side, and pass deeper in the jaw, and ultimately get beneath them, acquir- by degrees their alveolar cavities, and being closely and some- t irregularly packed. As the anterior molar is developed, it soon es to occupy the tuberosity of the maxilla, and the base of the noid process in the respective jaws, and, afterwards, by the thening of the alveolar arch, descends into place on a level with e before it. As this occurs, the cavity of reserve, situated over urnishes the papilla and sac for the second molar, which soon ipies the tuberosity or coronoid process, and then descends to ind the anterior one, a portion of the cavity of reserve being still to furnish the hindmost molar or wisdom tooth in the same man-

As these several teeth descend to the alveolar arch, the jaw is ortionally lengthened by a suitable addition from behind; so that circular arch, of which the alveoli at first consisted, is altered into illiptical one.

s the permanent teeth are being prepared to penetrate the gum, bony partitions, which separate their sacs from those of the tem- ry teeth, are absorbed; the fangs of the temporary teeth are re- ed by a very singular natural process; and the permanent teeth

come to be placed directly under the now loose crowns of the temporary ones, which finally detach themselves and allow the permanent teeth to take their places in the mouth. While it is impossible not to admire the evidence of design furnished by this exquisite process, it seems sufficient to assign it physiologically to that general law which determines the form and size of the several parts of organized beings. It has been supposed that elongated productions of the cavities of reserve, which have been carried down from the surface with the permanent tooth sacs, serve to re-direct them to their proper places as they rise through the gum. But it may be asked what served previously to carry down the pulps aright, and to form these gubernacula? It is manifest that we must ascend to a higher secondary law, to which to refer these wonderful phenomena of life.

The periods of eruption of the permanent teeth, though liable, like those of the milk teeth, to some variety, are, according to Mr. Bell, usually as follow:—the anterior true molars at 6½ years of age, the central incisors at 7, the lateral ones at 8, the anterior and posterior bicuspids at 9 and 10, the canines from 11 to 12, the second true molars from 12 to 13, and the wisdom teeth from 17 to 19.

Of the Jaw-bones at different Ages.—The bones undergo some interesting changes of form in connection with the growth and decay of the teeth, which have been well explained by Hunter. The alveolar processes in both jaws appear with the teeth, and disappear when no longer needed to support and enclose them. In the fœtus, before the eruption of the teeth, the upper gum is about on a line with the articulation of the jaw, the lower, consequently, is nearly on the same line, and the angle of the jaw very obtuse. But as the teeth protrude, and increase in number, the lower jaw is separated from the upper by the depth of the alveoli and crowns of the teeth of both jaws, the body and ascending ramus are both lengthened, and the angle approaches nearly to a right angle. When the teeth are subsequently shed, the alveoli disappear, and the lower jaw has to be much more elevated in order to touch the upper. But as its body and ramus cannot return to their former dimensions, its anterior part is thrown a good deal beyond the upper in this action, and it is only the hinder portions in the situation previously occupied by the molar teeth which come into contact.

Of the Articulation of the lower Jaw, and the Movements of Mastication.—A constant relation subsists in animals between the nature of the food, the shape and structure of the teeth, and the articulations of the jaw; so that, as Cuvier demonstrated, one of these elements being known, the others may be more or less accurately inferred. Thus, the purely carnivorous animals have teeth fitted to seize and lacerate their food, and the jaw is capable only of the simplest hinge motion. In the herbivorous families, on the contrary, teeth of a complex kind are provided for pounding and bruising the food, and the joints are so constructed as to allow of extensive sliding motions; while in all there is an inter-articular fibro-cartilage for protection under the extreme pressure exerted. The form of the articulation in man, not less than the dental series, denotes an intermediate condition, and

hysiological argument for the mixed diet, which gene-
aste have decided to be natural to our species. As
;, tearing, and grinding teeth, all in moderate propor-
height, and in an uninterrupted row, so the articula-
s intermediate between those of the animal and vege-
The transverse condyle is received into the glenoid
ie slighter movements of mastication and articulation
it; but when the grinding teeth are used, or the
l wide, the condyle leaves the cavity, and slides for-
an inch on the prominent root of the zygoma. In
the axis of motion is not in the condyles, but a little
of the jaw, and the joint is arthrodial. A similar
condyles may occur with the mouth nearly closed,
rs being then carried to a level with, or even beyond
By the advance of one condyle a partial rotation is
itre of motion being in the other condyle; and when
l alternately by both sides, together with an elevation
lower molars are moved laterally over the upper, so
y grind any intervening substance. The temporal,
internal pterygoid muscles more or less directly close
hinder fibres of the temporal and masseter carry it
while the main part of the masseter, and especially
ygoid, advance it. Both pterygoids carry it to the
iefly by advancing its ramus, the centre of motion
he opposite joint. The external pterygoid neither
esses it. The depression of the jaw in mastication
ormed solely by the digastric; and it may be conjec-
this muscle acts chiefly in its anterior belly, which,
ior, is supplied by the inferior maxillary nerve, the
istributed to the other muscles of mastication.

m.—The *salivary organs* consist of glands opening
nd pharynx, and furnishing a peculiar fluid which is
h the food and carried down with it to the stomach.
e the parotid, submaxillary, and sublingual; and to
ded a multitude of small detached glands of similar
robably yielding a similar fluid, scattered under the
ne of the lips, cheeks, soft palate, and parts of the
duodenal glands, comprising the pancreas and the
er, which have much in common with the salivary
lescribed at a subsequent page.

glands need not here be severally described. The
kable for its proximity to the temporo-maxillary ar-
ome have attributed its greater activity during mas-
essure to which it is supposed to be then subjected;
the fact of pressure may be doubted, so mechani-
s seems quite superfluous, since the nervous sympa-
vidently stimulate or control other secretions, as the
ufficient to explain this. The parotids pour their
hat compartment of the mouth which is outside the

teeth, while the ducts of the submaxillary and sublingual glands open under the tip of the tongue within the alveolar arches.

The salivary glands consist of a single excretory duct, continuous with the mucous membrane, branching again and again towards the gland, so as to subdivide it into a multitude of lobes and lobules invested with subdivisions of a common areolar or fibrous capsule, and reducible ultimately to follicles of a highly delicate basement membrane, lined by glandular epithelium, and provided on their exterior with a network of anastomosing capillaries. Some anatomists consider that the ultimate follicles of these glands, in which the secretion is elaborated, are at first closed sacs, in which the epithelium grows and is multiplied, and which discharge themselves at stated intervals into the extremities of the duct. Knowing how difficult it is to determine the positive truth on this question, we shall merely say that we are disposed to regard the secreting follicles as permanently open to the duct, and their secretory epithelium as a continuation of that which lines the duct.

Salivary glands exist in all the vertebrata except fishes.

The mere sight, or even the idea, of food to a hungry man, excites the salivary secretion—"makes the mouth water;" and during mastication it is poured very abundantly into the mouth, especially at the commencement of a meal, or if the food taken is of a savoury quality. Ordinarily, between meals and at night, these glands hardly pour out any secretion; but there can be little doubt that in these intervals of comparative repose of their blood-vessels, the epithelium of the follicles is undergoing those processes of growth and change which precede the actual formation of the salivary fluid; and the same may be said of many other glands which have an apparently intermittent action. The quantity of saliva furnished in a given time in a state of health has been variously computed. Mitscherlich collected between two and three ounces from the parotid duct in the course of twenty-four hours, and nearly fourteen from the whole of the salivary organs; and his estimate appears worthy of being relied on.

The *saliva* is a slightly viscid transparent fluid, depositing a little flocculent sediment on standing, which consists principally of the scaly epithelium of the mouth, and of other smaller nucleated cells, which seem to come from the salivary glands or ducts. Its viscidity is increased by mixture with the mucus of the mouth. According to Dr. Wright, its specific gravity is, on an average, about 1007·9. It is usually alkaline, especially during a meal, but often neutral, and sometimes slightly acid. Less than two parts in a hundred are organic or saline matters, the rest is water. The organic matters are (besides the nucleated cells) ptyalin or salivin, fat, (often visible as oil-globules in the microscope,) and extractive matter, with a trace of albumen; the inorganic constituents are alkaline lactates, chlorides of sodium and potassium, phosphate of lime, some free soda, with sulpho-cyanide of potassium, and perhaps others. The last named product gives a red tinge with a persalt of iron, and seems peculiar to the saliva. With regard to the nature and properties of what has been termed ptyalin, chemists appear to be by no means agreed, or even whether

be at all peculiar to this secretion. Dr. Wright, who has paid a eat deal of attention to the saliva, describes it as a yellowish-white, lhesive, and nearly solid matter, having alone the characteristic lour of saliva, soluble in ether, alcohol, and essential oils, but more paringly so in water; as unaffected by most of the agents which coaplate albumen, but as abundantly precipitated by subacetate of lead ad nitrate of silver. Dr. Franz Simon, on the contrary, describes ptyalin as insoluble in alcohol and ether; and he adds, "Our knowledge of this substance is by no means accurate; and there is no loubt that all the animal fluids yield an extract to water, which rongly resembles, if it be not altogether identical with ptyalin." *Animal Chemistry, translated by Geo. E. Day*, (London, 1845,) p. 24. Dr. Miller has published a recent analysis of the saliva. *Cyclop. Anat., art. Organic Analysis*, p. 812.

An obvious use of the saliva is to aid in reducing the food to a ultaceous form, in which it is more easily swallowed. During the movements of mastication, it is intimately mingled with the whole mass, and may thus very probably enable the gastric juice to penetrate more quickly to every part on its arrival in the stomach. But general experience attributes the ill-effects of rapid eating or bolting of the food, to the saliva being swallowed in insufficient quantity, as well as to imperfect mastication; and it is a question of some interest, to ascertain whether this fluid has any digestive powers, at all allied to those of the gastric juice. The experiments f Leuchs have proved that it has the power of converting starch into sugar, a change similar to that which occurs in the stomach; and Spallanzani observed that aliments enclosed in perforated tubes, and introduced into the stomachs of living animals, were earlier digested, when previously mixed with saliva, than with water.

Dr. Wright injected saliva into the blood-vessels of dogs, and found the animals dying in a few days or weeks, with symptoms much resembling those of hydrophobia. In other instances, where e employed white of egg, isinglass, and mucus, no such effects ensued. *Lancet*, 1844. *Br. and For. Med. Rev.*, Jan. 1847.

Of Deglutition.—The parts concerned in this act are the mouth, the pharynx, and the œsophagus, the two latter of which remain to be considered.

The *pharynx*, as usually described, consists of all that cavity lined with mucous membrane which is situated in front of the cervical vertebræ, behind the nose, mouth and larynx, below the base of the skull, and above the œsophagus. This cavity, however, as we shall show, comprises two parts entirely distinct from one another: an upper, with its walls never in contact, lined with ciliated epithelium and containing air, which we shall term the *respiratory compartment*, being in fact strictly a portion of the air-passages; and a *lower*, dilatable and contractile, lined with scaly epithelium, and giving passage to the food from the mouth to the œsophagus, which we shall term the *alimentary compartment*, as it is a portion of the alimentary tube.

The air-passages are interrupted between the upper compartment and the glottis, and in this interval the air has to traverse the lower or alimentary compartment in its course from the nose to the lungs. The alimentary and respiratory tubes may thus be said to intersect each other in this common cavity, a fact of leading importance to the understanding of the anatomical arrangement of these parts. Not to speak of the laws of development to which this free communication of the two great tracts ministering to the nutrient function may be referrible, (a communication still freer previous to the fusion of the sides of the palate at an early stage of fœtal existence,) it may be sufficient to allude to the great end answered by it, viz. the bringing the whole apparatus of the mouth into connection with the lungs for articulation and speech, and to the subordinate object of much heightening the sense of taste during mastication, by allowing the odour of the food to ascend from the mouth and pharynx to the olfactory region through the posterior nares. (See p. 388.)

From the hinder border of the hard palate passes *the soft palate*, a fold of mucous membrane enclosing mucous glands, a fibrous substratum, and several muscles by which it is capable of various motions. This terminates below by a free border, with the uvula in the centre; and from this border on each side descend the two pillars of the soft palate: the *posterior* downwards and backwards, enclosing and marking the course of the palato-pharyngeal muscle, and dividing the alimentary compartment before alluded to from the respiratory one above; the *anterior* downwards and forwards, containing the much smaller palato-glossus muscle, and dividing the same compartment from the mouth. Thus, this alimentary tract of the pharynx may be said to have its upper part included within the diverging pillars of the soft palate, with the tonsils projecting into it, and to have its summit formed by the lower edge with the uvula, the posterior or upper surface of the soft palate pertaining to the respiratory tract, and the anterior or lower to the mouth. The mucous membrane of the pharynx seen between the soft palate and tongue on opening the mouth lies above the posterior pillars, and consequently belongs to the respiratory compartment; and we have on several occasions had interesting proof of this in those cases of chronic syphilis attended with a dry state of the pharyngeal membrane, and in which this part has remained dry after the patient has been made to swallow water.

The alimentary compartment of the pharynx has four orifices, all capable of closure; one towards the mouth, bounded by the lower edge and anterior pillars of the palate, by the base of the tongue and os hyoides; another towards the œsophagus, at the lower border of the cricoid cartilage: these two are alimentary. The third opening is towards the upper compartment, and is bounded by the lower border of the palate with the uvula, and by the posterior pillars with a portion of the posterior wall; the fourth is towards the lungs, and formed by the upper part of the larynx defended by the epiglottis; these two are respiratory. The shape of the alimentary compartment is very irregular, and capable of great alteration by the movements partly of the os hyoides and tongue with the larynx, and partly of

the constrictor muscles forming its back and sides. Much lax areolar tissue, containing no fat, surrounds it, and allows of these movements on the contiguous parts. As it is impossible in the compass of this work to include a special description of the muscles and other constituents of the pharynx, we must suppose the reader to have already made himself acquainted with them from the ordinary sources.

The soft palate contains a thick layer of glands under its mucous membrane, in front of its muscles; and great numbers are situated about the upper orifice of the larynx and on the general surface of the pharynx. The *tonsils* are large and somewhat peculiar glands projecting between the arches of the palate. They open by several distinct orifices, which lead into cells, around which the secretory structure is arranged. They are very vascular organs, and evidently placed where they are to lubricate the food in its passage from the mouth. It is not, however, known with accuracy what is the nature or composition of the secretion they furnish; but it is, probably, little besides simple mucus. That it is not identical with the saliva may be inferred from the difference in structure of the glands, and from the tonsils being liable to inflammation and suppuration, as well as to strumous enlargement, while the salivary glands are seldom or never affected in the same way.

The food when sufficiently comminuted and mingled with saliva in the mouth, and collected in the hollow of the tongue, is thrown into the alimentary pharynx by the tongue being pressed upwards against the roof of the mouth—this movement beginning at the tip, and ending near the base. The division of the pharynx which is to receive it is dilated as the food enters, by the advance and elevation of the larynx, and by the yielding of its sides and posterior wall, while the communication with the respiratory compartment above is effectually closed by the coming together of the posterior pillars of the fauces, by the contraction of the palato-pharyngeal and upper constrictor muscles. The base of the tongue is now forced backwards and upwards, so that the pellet is pressed between it and the soft palate with its posterior pillars now in contact, and is thereby carried downwards and backwards into that portion of the cavity which lies behind the larynx. It crosses over the glottis without entering it, because while the larynx is advanced the base of the tongue presses back the epiglottis, and so covers the orifice; this movement of the epiglottis being assisted by the small aryteno-epiglottidean muscular fibres, and by the very course of the food itself; but it is abundantly proved, that even without an epiglottis the glottis would for the most part be so closed by sudden spasm of its constrictors, as to prevent any alimentary matters from falling into the larynx. In the act of vomiting, where the matters pass in the contrary direction, it is probable that the glottis is partly protected by the backward position of the tongue and epiglottis and partly by this conservative contraction of the arytenoid muscles in answer to the mechanical stimulus of the food on the mucous membrane in the vicinity. The pellet of food having arrived near the œsophagus, is projected into it by the contraction of the

middle and inferior constrictors, the upper portion of that canal being dilated by its entrance.

It might be imagined that a process which may thus be artificially divided into consecutive stages, and which combine so many elaborate and harmonized actions, would occupy something more than a single second in its performance. It is, however, quite momentary. The movements cannot be performed separately by any voluntary control; the food once willingly thrown by the tongue beyond the isthmus of the fauces cannot be recalled, but is necessarily carried forward to the stomach—a beneficent provision, in which the physical supersede in a great degree the mental nervous actions, to ensure the integrity of the vital function of respiration. On the action of the nerves, however, we need add nothing to what has been already stated (see 296, 306, 307, 487 and 488).

The *œsophagus* is a tube continuous with the pharynx, fitted to convey the food past the organs of respiration and circulation in the thorax to the stomach below the diaphragm. It first lies upon the vertebræ and inclines slightly to the left, but afterwards, in its course through the posterior mediastinum, it advances in front of the descending aorta, and occupies the median line. It is surrounded in its whole length by a lax areolar tissue, which permits its dilatation and contraction during the passage of the food. It has a strong muscular coat composed of two layers, an outer, of longitudinal fibres, which commence from the cricoid cartilage; and an inner, of circular fibres: both these spread out upon the stomach, and become much thinner on that organ. The fibres of both layers are of the striped kind in the upper part and for a variable way down, some being often traceable as low as the diaphragm. In the middle region, unstriped fibres are mingled with the others; and in the lower part they are either the chief or only constituent. It has also a mucous lining, continuous with that of the pharynx and stomach, but different from both, being covered with a thicker and more opaque epithelium, resembling cuticle, and thrown, when empty, into longitudinal folds by the help of an abundant areolar tissue between the coats. Among the creases, chiefly in the lower third, are scattered mucous glands, which open on the surface, and serve to lubricate the canal during the passage of food. The cuticular lining of the œsophagus is changed abruptly at the cardiac orifice of the stomach into the glandular lining of the latter organ. Thus the œsophagus is organized as a simple conduit. It has considerable muscular power, and a comparatively thick and insensible lining membrane.

On receiving the morsel forced into its upper orifice by the last act of pharyngeal deglutition, the œsophagus is mechanically dilated, and its lining membrane stimulated by the contact. The result is a contraction of its muscular coat upon the pellet, which is thereby carried forwards into the succeeding portions, in which the like actions are induced, until it has traversed the entire canal. This series of actions is rapid and quite involuntary, but an obscure sensation attends it, which is capable of being heightened to uneasiness or pain if any obstruction be met with, or if the descending morsel be

oo hot. It has been already stated that the contractions are due to a central stimulus on the muscular nerves, derived from the pressure of the food on those of the lining membrane (see p. 490). It has, been pointed out by Müller that rapid and slight peristaltic descending contractions occur in the œsophagus independent of the passage of food. These are probably such as occur in the intestines and uterus, without the accustomed stimulus and as a mere consequence of their contractility. In vomiting, the œsophagus has an inverted action, the muscular coat forcing up the food thrown into it from below. In ruminating animals, this inverted peristaltic motion is capable of being accomplished by the will, and a similar power exists in some individuals among mankind, of which we have witnessed more than one striking example.

On passing a rapid series of electrical shocks down the œsophagus of a dog just killed, the upper three-fourths of the tube are thrown into continued or tetanic contraction, while the lower fourth takes on a peristaltic or vermicular contraction; thus demonstrating the situation of the change from the striped to the unstriped fibres of the muscular coat, according to the recent test of Weber.

On the subject of the teeth the student may conveniently refer to the works of Leeuwenhoek, John Hunter, Thomas Bell; Tomes, Med. Gaz. 1839–46; Owen, Odontography; Nasmyth on the Teeth; Müller's Physiology, by Baly; Goodsir, Ed. Med. and Surg. Journal, vol. 51. On insalivation, he may consult Dr. Wright's works, which are of great interest and value. On deglutition, Dzondi's observations, in Müller, by Baly; a paper by Mr. Fergusson, in Med. Chir. Trans., vol. xxviii. p. 280; and the Cyclop. Anat., art. *Œsophagus*, by Dr. Johnson.

CHAPTER XXIV.

DIGESTION CONTINUED.—THE STOMACH.—ITS COATS, PARTICULARLY THE MUCOUS COAT.—STOMACH CELLS AND TUBES.—PYLORIC TUBES.—MOVEMENTS OF THE STOMACH.—THE GASTRIC JUICE, ITS NATURE AND PROPERTIES.—PEPSINE.—STOMACH DIGESTION.

THE alimentary canal below the diaphragm is naturally divided into the stomach, the small intestine, and the large intestine, all of which are lined by mucous membrane, have like the œsophagus, a double muscular coat, and are, besides, invested with a serous membrane, the peritoneum, which facilitates the motions by which the contained matters are propelled from end to end.

The stomach, of which we have first to speak, is an elongated curved pouch, very dilatable and contractile, fitted to receive the food from the œsophagus, to retain it while acted on by the gastric fluid secreted from the lining membrane, and then to transmit it to the duodenum or first part of the small intestine. It is expanded into an ample cul-de-sac at its left extremity, and becomes gradually narrower towards the pylorus, where it joins the duodenum. A cir-

cular constriction is often apparent three or four inches from the pylorus, partially dividing the pyloric region from the rest of the cavity. It has an anterior and posterior surface, which become respectively rather upper and lower during repletion of the organ (owing to its change of bulk, and its being fixed at its two orifices), and an upper and lower curvature, called also lesser and greater, which undergo a corresponding alteration, becoming rather posterior and anterior. The *peritoneum* invests both surfaces, and passes from them to the liver (forming the gastro-hepatic omentum), to the spleen (forming the gastro-splenic omentum), and to the transverse colon (forming first the anterior and then the posterior layers of the great omentum). This peculiar arrangement of the serous membrane is probably intended to allow of the extreme changes of bulk to which this organ is liable. The *muscular fibres* of the stomach are continuous with those of the œsophagus; but, in consequence of its irregular shape and its bulging from the cardia towards the left hypochondrium and the umbilical region, these fibres are not regularly longitudinal and circular as in the œsophagus, and as in the intestines. The outer or longitudinal set may be best traced along the lesser curvature and near the pylorus; and those beneath cross them either at right angles or obliquely, according to their situation. Towards the lesser extremity the fibres of both layers are much thicker, and particulary so at the pylorus itself, where they form a circular constriction projecting the lining membrane, and capable of acting as a sphincter muscle. They are of the unstriped variety.

The *mucous membrane* of the stomach is thick and soft, and thrown into numerous irregular folds by the contraction of the muscular coat, except in the distended state of the organ. To be capable of this folding, it is separated from the muscular wall by a very lax areolar tissue, containing no fat, but filled with the vessels belonging to the mucous membrane, and also containing nerves. This is the coat wrongly styled nervous by the older writers.

The stomach is freely supplied with blood by the three divisions of the cœliac axis, the coronary, hepatic, and splenic. The branches of the arteries reach it along its borders, soon pierce its muscular tunic, and form plexuses in the sub-mucous areolar tissue, where they break up into numberless finer ramifications, which penetrate the mucous coat. The veins accompany the arteries in their distribution and discharge themselves into the vena portæ. Both orders of vessels are very tortuous, and their contiguous branches everywhere anastomose freely, so as to distribute the sanguineous supplies equally during the changing volume of the organ. The nerves of the stomach are derived from the pneumogastrics and from the cœliac plexus. They advance from the lesser curvature over both surfaces, and after supplying the muscular walls, enter the areolar layer under the secreting lining membrane.

The mucous membrane of the stomach demands and will well repay an attentive study. It is of that variety which has been termed *compound mucous membrane*, i. e. its thickness is made up of an infinite multitude of tubular involutions of the simple membrane, with

liate vascular, and other tissues sent up into it from below. ple membrane consists of basement membrane and epithe- th of which are found throughout. The vessels are uniformly eep surface of the basement membrane, and the epithelium pposite surface. The compound mucous membrane of the is thinnest near the œsophagus, and is usually of a pinker ı the middle region, and paler towards the pylorus.

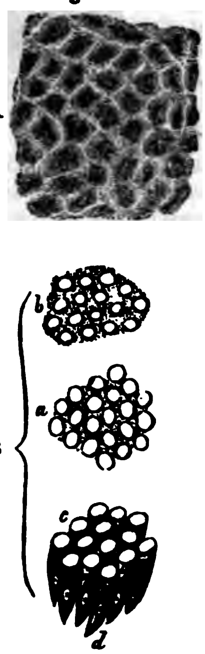
the whole surface of the membrane as seen on laying open n, and stretching it so as to obliterate the larger folds, there ble, even with the naked eye, but still better with a lens, a e of cavities of very irregular shape, and about $\frac{1}{300}$th of an liameter, more or less (fig. 154, A). These cells are not the creasings of the membrane, and they do not disappear when tched. They are usually filled with which requires to be removed. Over ter part of the stomach they extend only about $\frac{1}{8}$th or $\frac{1}{4}$th of the thick- the membrane, but they are larger per near the pylorus. In the ridges them runs a plexus of vessels larger linary capillaries (fig. 155 A, *d*), and ıften retains its blood after death, so ıp out the cells in a beautiful manner. exus is supplied by vessels sent up ow, and may be very easily injected ly.

pithelium which lines these stomach l covers the ridges between them is columnar variety (fig. 154 B); the ı are shorter than in some other parts: is free while the other is directed to- he basement membrane; and they each a clear pellucid nucleus near eper end. They seem to lie in a eries, the deeper being in course of ment while the more superficial is in f decay. It has appeared to us that rticle when arrived at maturity has, the nucleus, granular contents enclos- that at a subsequent period the gran- tents escape at the free extremity by ence or opening of the wall at that ıving the transparent husk with its subsisting for some time longer. ar structureless mucus which is al- ways found occupying the cells and the surface of the membrane seems e altered contents of these particles eir escape, for the uniform existence ıute cavity in the centre of it, where it fills the cells, show

Fig. 154.

A

B



A. Inner surface of the stomach, showing the cells after the mucus has been washed out. Magnified 25 diameters.

B. Columnar epithelium of the inner surface and cells of the stomach:—*a* Free ends of the epithelial particles, seen on looking down upon the membrane. *b*. Nuclei visible at a deeper level. *c*. The free ends seen obliquely. *d*. Deep or attached ends of the same. The oval nuclei are seen near the deeper ends.

From the dog. Magnified 300 diameters.

that it has oozed out from every part of their wall, so as gradually to fill them up (see fig. 155, A).

Fig. 155.

A. Horizontal section of a stomach cell, a little way within its orifice. *a*. Basement membrane. *b*. Columnar epithelium. All but the centre of the cavity of the cell is occupied by transparent mucus, which seems to have oozed from the open extremities of the epithelial particles. *c*. Fibrous matrix surrounding and supporting the basement membrane. *d*. Small blood-vessel.

B. Horizontal section of a set of stomach tubes proceeding from a single cell. The letters refer to corresponding parts. The epithelium is glandular; the nuclei very delicate; the cavity of the tubes very small, and in some cases not visible.

From the dog, after twelve hours' fasting. Magnified 200 diameters.

Fig. 156.

Vertical section of a stomach cell, with its tubes: A in the middle region, B in the pyloric region. *a a*, Orifices of the cells on the inner surface of the stomach. *b b*. Different depths at which the columnar epithelium is exchanged for glandular. *c*. Pyloric tube, or prolonged stomach cell. *d*. Pyloric tubes, terminating variously, and lined to their extremities with sub-columnar epithelium.

From the dog, after twelve hours' fasting. Magnified 200 diameters.

It has been said that the cells are so shallow as to dip into the compound membrane only about $\frac{1}{8}$th of its thickness. The rest of its thickness, except near the pylorus, is made up of minute tubular offsets from the bottom of the cells, which may be termed the stomach tubes, (fig. 155, B; and fig. 156,) and which pass vertically, two, three, or four from each cell, afterwards subdividing again and again, and becoming more or less tortuous, till they terminate by blind extremities on a dense tough layer of areolar tissue continuous with that laxer stratum which separates the mucous from the muscular coat.

The *stomach tubes* have a basement membrane, and contain an epithelium altogether different from that which has been just described. Its particles are of the glandular variety, are rounded in shape, without obvious walls; their contents are darkly granular, often mixed with oil globules, and their nucleus is less distinct. The tubes are

row that the particles seem to fill them, and obliterate their , except near their orifices, where they empty themselves into lls. Towards their blind extremities they often seem to be a series or pile of epithelial particles; and this has led some iists to deny that they are tubes. The existence, however, of nent membrane convinces us that they are to be regarded truly :s, permanently laid down in the tissue of the stomach, for the ition and discharge of the materials of their peculiar epithelial es on its inner surface. The tubes proceed in sets, correspond- the cells into which they open; those of each set being en- in a common envelope of nucleated tissue, like the matrix of lney and some other glands. This firm investing structure is :d on the one hand to the dense layer on which the compound ane rests, and on the other to the ridges between the cells; sends delicate processes between the individual tubules of each d between their branchings, so as to sustain every portion in per place. Between the sets of tubules the larger vessels run he ridges between the cells, and every tubule is invested with ries, which take for the most part an upward direction, and are oss with the tubules in a transverse section of the latter, (fig. , *d.*) We have met with no tubular nerve fibres in the mucous ane of the stomach; but it is highly probable that nucleated ibres run among the tubes, though their want of characteristic s renders it difficult to positively assert their presence.

description now given will hold good for the whole lining of mach, except near the pylorus. Here, in many of the lower s which we have examined,—for example, in the dog, and, it ith probability be inferred, in man also,—a change occurs in gradual manner, but evidently of an important kind. The ane is of a paler tint, and its cells seem not to terminate at the true stomach tubes already described, but are prolonged ich wider cylindrical tubes, lined with the same columnar epi-ı, and descending nearly or altogether to the deeper surface of npound membrane. For the most part, these prolongations of ls—or, as we shall term them *pyloric tubes*—end at length in iort and diminutive true stomach tubes (fig. 156, B); but we kewise found them terminating in either flask-shaped or un- extremities, lined throughout with the sub-columnar variety ielium, (fig. 156, *d.*) Thus in these animals a marked distinc- ists between the mucous membrane of the pyloric compartment it of the rest of the organ, a distinction which must undoubt- ve an important physiological meaning; and we have suspected digestive power of the two parts must differ; that the office pyloric tubes resembles that of the stomach cells generally, different from that of the true stomach tubes; that perhaps the oduct of the stomach may be furnished by one rather than by er. We confess, however, that we have been unable, on the id, to obtain human stomachs sufficiently fresh and healthy to fact of the anatomical distinctness of the two regions in man, the other, to ascertain the value of the conjectures just alluded

to as applied to animals in which the twofold structure is sufficiently certain.

It is necessary to examine the changes that occur in the stomach upon the introduction of food in it. These changes are threefold:—1st, as regards its muscular coat; 2d, as regards its mucous membrane; and, 3d, with respect to the nature and properties of the secretion which is derived from that membrane.

1. *Movements of the Stomach.*—On exposing the stomach of a living animal, or of one recently killed while digestion is going on, we find that it firmly embraces its contents, and that both orifices are closed, so as to prevent the escape of the food. This is particularly the case as regards the pyloric orifice in the first period of digestion. The contraction of the circular muscle which surrounds the pylorus is so strong, that, even after the stomach has been separated from the intestines, its contents do not escape for some time.

This contraction is due to the stimulus of the food; and, when the aliment is difficult of digestion, the muscular coat is proportionably stimulated.

The movements of the stomach are very different in its cardiac and in its pyloric portions. In the cardiac, two-thirds the movements are very slow and scarcely perceptible, and seem to consist in little more than a firm and steady contraction upon the contents, the muscular coat thus slowly pushing on the food towards the pyloric portion, and adapting itself to the diminished size of the organ. In the pyloric portion they resemble closely the peristaltic movements of the intestinal canal, which indeed appear, as it were, to start from the junction of this portion of the stomach with its cardiac portion. Under the influence of the magneto-electric apparatus this mode of contraction of the pyloric fibres may be well shown in dogs or cats just dead, and the contrast with the action of the cardiac fibres may be strikingly displayed.

We had lately an opportunity of observing the peristaltic character of the movement of the pyloric portion of the stomach during life, in a woman in whom that organ was so enormously enlarged as to occupy nearly the entire abdominal cavity, the intestines being pushed into the pelvis, and the arch of the colon lying behind the stomach. The patient was so emaciated, and the abdominal parietes so attenuated, that the action of the viscus could be distinctly seen through them; and it appeared to resemble precisely the vermicular action of the intestines, for which, indeed, it was taken, as the nature of the case could not be distinctly recognized during life.

When the action of the stomach is energetic, a constriction is produced, by which the pyloric third is separated from the cardiac portion, thus giving rise to the hour-glass contraction, which continues for some time after death if the animals have been killed at the moment of its occurrence. The same condition may be produced by the magneto-electric apparatus. This constriction has been noticed by all observers in dogs and cats, and may be now and then seen in the human stomach. In some animals such a division between the

ions of the stomach exist in the natural conformation of the

uscular action of the stomach in man and the mammalia seems o push on the food into the intestine, and not to subject it to ration or mechanical reduction, according to the views of ologists of the early part of the last century. Reaumur, and Spallanzani, introduced into the stomachs of dogs and cats d tubes, made some of brittle and others of flexible materials. ere found quite unaltered by the action of the stomach, al- he portions of food contained in them were softened and

anges in the mucous membrane of the Stomach.—The gastric membrane of the stomach of an animal killed during stomach exhibits a faintish red and swollen appearance, due evidently reased afflux of blood, excited by the stimulus of the food. log this redness is limited in a very marked manner to the wo-thirds, the pyloric third presenting a white colour and a appearance, from the existence of numerous minute folds which stretching does not obliterate. At the same time the rface of the membrane is covered by a layer of mucus, which its thickness and in its viscidity.

be inferred from Beaumont's observations, that similar phe- are met with in the human stomach. Beaumont found that, tely on the introduction of food into the stomach, the vessels ucous membrane became more injected, much, no doubt, as the conjunctiva of the eye would become filled on the ap- of a foreign body; and that its colour became deeper, being from a pale pink to a deep red. A pure, colourless, and riscid fluid, with distinct acid reaction, was then observed to m the surface of the membrane, and to collect in drops at oints of it, trickling down the wall of the stomach until it with the food. The exudation of this fluid was always ex- the contact of any foreign substance; even so smooth a sub- the bulb of a thermometer invariably excited it on its intro- and even when it had been previously ascertained that the was empty, and exhibited no reaction.

g fasting Mr. Beaumont observed no evidence of the exist- such a fluid as this, the sole contents of the stomach being ly a little viscid mucus, occasionally slightly acidulated. t describes this fluid as being clear, transparent, inodorous, nd resembling in taste thin mucilaginous water slightly acid- ith muriatic acid. It is, he states, readily diffusible in water, spirits, and effervesces slightly with alkaline carbonates. It es albumen, and is powerfully antiseptic, checking putrefac- meat. When pure it will keep for many months; but if with saliva, it becomes fœtid in a few days. According to sis of Professor Dunglison it contained free muriatic and ids, phosphates and muriates of potass, soda, magnesia, and

ont's observations were made during a period extending be-

tween May, 1825, and March, 1833. Various observations and experiments, commencing from a date long antecedent to this, had led to a very generally received opinion among physiologists that the mucous membrane of the stomach was the seat of a special secretion, which had a great share in affecting the changes which the food undergoes in the stomach.

Reaumur was the first to offer satisfactory proof of the secretion of a solvent fluid for the purposes of digestion by the walls of the stomach. He obtained some of this fluid by making animals swallow sponges, which he could draw out of their stomachs by a string attached; and thus he was enabled to institute experiments on artificial digestion, so as to show that alimentary substances out of the body could be altered by this fluid in the same manner as they are changed in the stomach. He likewise introduced food into the stomachs of animals in perforated tubes, whereby they were defended from the pressure of the walls of the stomach, but could imbibe its fluids. His experiments disproved the favourite theory of the day, which ascribed all changes of the food in stomach digestion to the influence of trituration upon it by the action of the muscular coat of the stomach: they showed that the trituration in the gizzard of birds was no more than mastication by teeth in other animals, and that digestion was accomplished in birds of prey, dogs, &c., and probably in man, by the action of a fluid which exerted a solvent influence upon the food. *Mem. de l'Acad. des Sciences*, an. 1752, pp. 705-752.

Spallanzani likewise illustrated this subject by numerous experiments upon vertebrate animals of all classes, and even upon himself. Following the plan of Reaumur, he obtained the gastric juice by means of sponges, and he introduced food into the stomachs of animals enclosed in perforated tubes and balls. His essay on the subject of digestion is one of the most interesting dissertations in the literature of physiology, and is full of facts proving the secretion of a fluid capable of reducing and dissolving alimentary substances.

Stevens availed himself of a rare opportunity of investigating the effects produced on food in the human stomach. A hussar had accustomed himself at the early age of seven to swallow stones and other hard bodies; and, having continued the practice during twenty years, what had originated in idle amusement was now resorted to as a regular profession, to supply the necessaries of life. When Dr. Stevens first saw him, his stomach was so distended, apparently by the considerable weight to which it was repeatedly exposed, that he could swallow several stones at once, which were not only felt in the stomach, but might be heard by the bystanders moving against each other when the hypogastric region was struck.

Dr. Stevens made this man swallow perforated silver balls, containing sometimes raw animal food, sometimes vegetable substances; in general, raw animal substances suffered less than those which were roasted or boiled; roasted or boiled animal substances which had been mechanically divided were most completely acted on; the sub-

contained in balls with large holes were more completely on than those contained in balls with minute holes; and, the various vegetable grains, as wheat, rye, barley, oats, and rere least of all altered, having only become moistened and ı, while bone underwent no change.

Stevens also introduced leeches and earthworms in his per- l spheres, and found that even these animals, though intro- living, were dissolved as inanimate matters.*

ı Hunter made some observations which furnished an inter- proof of the existence of a solvent gastric fluid. He was with the condition of the stomach in two cases of sudden and death. A man had his skull fractured by a single blow of r; just before the accident he was in perfect health, and had a hearty supper. Upon opening the abdomen, he found that mach, though it still contained a good deal, was dissolved at at end, and a considerable part of its contents lay loose in neral cavity of the belly; a circumstance, he adds, which l him very much. The second instance was in a man who ; St. George's Hospital a few hours after receiving a blow on ıd which fractured his skull. In both these cases the solution the splenic end of the stomach; the edges of the opening e mucous membrane for some distance within were half dis- "very much," says Hunter, "like that kind of digestion fleshy parts undergo when half digested in a living sto- or when acted upon by a caustic alkali, viz., pulpy, tender, ."

these cases," Mr. Hunter adds, "the contents of the stomach nerally found loose in the cavity of the abdomen about the and diaphragm; and in many subjects the influence of this ve power extends much farther than through the stomach. I ften found, that, after the stomach had been dissolved at the ›lace, its contents, let loose, had come into contact with the and diaphragm, had dissolved the diaphragm quite through, ıd partly affected the adjacent side of the spleen; so that ad been contained in the stomach was found in the cavity of ›rax, and had even affected the lungs to a small degree."

ıere are very few dead bodies in which the stomach at its ·nd is not in some degree digested; and one who is acquainted issection can easily trace these gradations. To be sensible of fect, nothing more is necessary than to compare the inner › of the great end of the stomach with any other part of its surface: the sound portions will appear soft, spongy, and ated, and without distinct bloodvessels, opaque and thick; the others will appear smooth, thin, and more transparent, e vessels will be seen ramifying in its substance; and upon ing the blood which they contain from the larger branches to

De Alimentorum Concoctione, Edinb. 1777 (in Smellie's Thes. Med.).

the smaller, it will be found to pass out at the digested ends of the vessels, and to appear like drops on the inner surface."*

Hunter remarked that solution of the stomach is very commonly found in fishes, which almost always die a violent death, and frequently during digestion.†

Dr. Carswell investigated this subject, and obtained results confirmatory of the views of John Hunter. He killed rabbits and dogs during the digestive process, allowing them to lie for various periods after death. If examined four hours after death, he found that the solution had affected the mucous, submucous, and muscular tunics; when six hours had elapsed, the peritoneal coat was found softened, in addition to the others; the stomach was consequently perforated, and the food passed through the opening and came in contact with the liver, spleen, diaphragm, and intestines, one or all of which exhibited the same kind of softening as that found in the stomach, at those places where the digested food touched the parts. In another series of experiments, where the animals were suffered to lie for a still longer period after being killed, perforation of the diaphragm or œsophagus had taken place, and the liquid part of the food had flowed into the cavity of the chest, causing digestion and softening of the pleura and of the lungs.‡

3. *The Gastric Juice.*—From these various sources we derive the most ample evidence of the existence of a fluid secreted by the walls of the stomach during digestion, capable of exerting a reducing or solvent influence upon food. This fluid is the *gastric juice*—the *succus gastricus.*

It is of great importance to a correct theory of digestion to determine the precise composition of this fluid. Dr. Prout, in this country, in 1823, two years prior to the commencement of Beaumont's experiments, had determined the existence of an acid fluid secreted during digestion, and had analyzed it in the rabbit, hare, horse, calf, and dog. And he announced, as the result of his analyses, "that free or at least unsaturated muriatic acid, in no small quantity, exists in the stomach of those animals during the digestive process." And in later publications, Dr. Prout has reasserted this statement.

The weight which is so deservedly attached to the opinion of this eminent philosopher has, no doubt, had great influence in determining the prevalent opinion in this country in favour of the view which attributes the acidity of the gastric fluid to the existence of free muriatic acid in it. The source of the acid, it is generally believed, is the chloride of sodium of the blood, which at the mucous membrane of the stomach contributes muriatic or hydrochloric acid to the gastric juice, leaving free soda to be carried to the liver by the veins of the stomach.

* Hunter's Animal Economy, Owen's edition, p. 119.

† Spallanzani confirmed Hunter's statements.

‡ Ed. Med. and Surg. Journal, vol. xxxiv. p. 262. See also an excellent delineation of this *post-mortem* condition, by Dr. Carswell, in his "Illustrations of the Elementary Forms of Disease," art. *Softening.*

iment, however, shows that muriatic acid has little or no)ower on the food, and that the reducing action of the gas- cannot be attributed to it alone. Albumen or meat sub- the action of water acidulated with muriatic acid, and kept hours at a temperature of 100°, undergoes no change importance: neither substance exhibits any softening or to putrefaction or decomposition of any kind. Similar ents with acetic acid or with phosphoric acid lead to like

lain, then, that the solvent powers of the gastric fluid are simply to the acid which it contains, whatever that may be, we must look for some other ingredient in it, which, either in combination with acid, can exercise these powers. The this was given by Eberle, who adopted the expedient of o water acidulated with muriatic acid a small piece of the membrane of the stomach. By this means he succeeded in g a digestive fluid which reduced animal substances as per- the gastric juice itself.

liscovery was of the last importance to the formation of a theory of stomach digestion, and to exact views of the nature astric juice. It was soon followed up by numerous experi- Germany, by Schwann and Müller, and by Purkinje and eim. The general result of these experiments was, that ition of a portion of gastric mucous membrane from the reting stomach to an acidulated water produced a perfect fluid; but that no other mucous membrane would answer pose. The following changes take place on macerating meat men in a digestive fluid: The meat is broken down to a pulp; and if the digestion have been continued sufficiently is dissolved. The albumen is likewise equally softened. ly changes which take place in a cubic piece of solid white macerated in the digestive fluid, are very characteristic. s become of a pearly hue, semi-transparent, almost fluid, down under the slightest touch of the finger; and, after igestion, the solid matters are completely dissolved.

olvent power of a digestive fluid made with the mucous ne of the stomach is strikingly displayed if the results of stion of meat and albumen with it be compared with those l by digesting pieces of the same substances either with acidulated water — muriatic, acetic, or phosphoric acid ed—or with an infusion of mucous membrane without acid. acidulated fluids produce little or no change in meat and in the course of twelve or twenty-four hours; and such as is produced presents a marked contrast to that caused by sion of mucous membrane with acid. No acid, however, to cause more change than the phosphoric. When the of mucous membrane is used *without* acid, rapid putrescence ced. A similar effect results, although with less intensity, use of too little acid; and, if alkali be added, the putre- becomes still more rapid and intense.

In these experiments, it is of great importance to pay close attention to the temperature. It should be within the range of from 90° to 110°, the higher temperature increasing the energy of the digestive action. If it reach the point at which albumen is coagulated, all solvent change ceases, and the meat or albumen becomes hardened. In a low temperature, likewise, there is no change; the digestive fluid under such circumstances serving merely to prevent decomposition.

The *antiseptic power* of an acid infusion of gastric mucous membrane is one of its most remarkable properties; and in this respect it resembles the gastric fluid itself, which, according to all observers, is remarkably antiseptic, being capable of checking the further progress of putrefaction in meat in which that process had already begun. This power seems principally due to the acid, the neutralization of which destroys it; and if an infusion of mucous membrane to which enough acid had not been added become putrescent, its further decomposition may be checked by the addition of more acid. We have kept the artificial digestive fluid for many months in a bottle with a common cork without its undergoing any change.

The gastric fluid possesses the property of causing the coagulation of the caseine of milk; an artificial digestive fluid made from the mucous membrane of the true stomach of ruminants possesses the same power, even if its acid be neutralized by potass. This fact has been long known to the makers of cheese; and the dried mucous membrane of the fourth stomach of the calf has been used, under the name of rennet, for the purpose of coagulating that principle in milk. That it possesses this power independently of any acid which it may contain, was first pointed out by Berzelius. Some have affirmed that this power belongs only to the mucous membrane of the stomach of sucking animals.

A fluid of such digestive power as that above described cannot be made from any mucous membrane but that of the stomach. The mucous membrane of the bladder, of the greatest portion of the intestinal canal, is quite insufficient for this purpose; but that of the duodenum appears to exert some solvent influence.

The Organic Principle of the Gastric Juice.—All these facts show that the gastric mucous membrane contains some material, which, when dissolved or diffused in acidulated water, exercises a power not to be distinguished from that of the gastric juice itself. Can this material be isolated? There is no doubt that we can obtain from the mucous membrane of the digestive stomach of animals, an organic substance, which exhibits reactions in close analogy with those of albumen, and which exercises a solvent or catalytic influence upon various azotized substances; to this substance Schwann and Müller gave the name *pepsine*.*

Valentin very justly remarks that the organic combinations upon which the solvent power of the gastric fluid depends, share the same fate with other contact substances, namely, that they cannot be ob-

* Also called *gasterase*, by French writers.

ed in perfect purity, nor can their precise relative proportions determined with exactness. Pepsine, therefore, he adds, can be regarded as an hypothetical or conventional name for an unwn mass which may be separated by alcohol, or by lead and alol in combination with other bodies. Nor do the reagents indie any definite character—they only afford conjectural information. view it as a kind of diastase, whilst it does not remove our diffity, nevertheless denotes the power of the unknown substance in ore precise and definite manner.

An artificial digestive fluid may be made in the following manner. a piece of the mucous membrane of the stomach of a pig be erated in distilled water for twelve hours at the temperature of or 100°; afterwards, add dilute muriatic acid to the fluid until edissolves the precipitate which is at first thrown down; the fluid formed will be found to possess full digestive powers, and all properties of the gastric fluid. It is, in fact, an acidulated soion of pepsine in water. The pepsine may be precipitated from solution by some of the reagents which coagulate albumen. hloride of mercury will do this, and render the fluid inert. Alol and water at the boiling temperature produce the same effect; precipitate, however, thrown down by alcohol, is capable of being issolved in water, and then, with acid, will produce a digestive d. Tannin also precipitates it. It is evident, therefore, that the estive fluid contains a principle capable of affording distinct reions. The solvents of this principle are water and dilute muriaor acetic acids.

The power which the digestive fluid has of coagulating caseine, *lependently of its acid*, denotes that it holds in solution some cial agent derived from the mucous membrane of the stomach.

Alcohol added to a fresh infusion of mucous membrane throws rn a white flocculent precipitate, which may be collected on a er, and when dried will produce a gray compact mass. This, en redissolved in water, will exhibit digestive powers, and these vers are greatest when it is united with acetic and muriatic acids. obtain in this way the nearest approach to the isolation of pepe.

The Acid of the Gastric Juice.—Of the existence of an organic nciple, a secondary organic compound, the product of the secrey action of the mucous membrane of the stomach, no doubt can entertained; but we can speak with less certainty of the nature the acid which exists along with it in the gastric fluid of the mach, inasmuch as recent observers have thrown a doubt upon correctness of Prout's opinion. The following are the most reit opinions put forward on this subject.

Blondlot affirms that the acidity of the gastric juice is due not to presence of a free acid, but to the existence of *biphosphate of e* as one of its ingredients. To this, however, Melsens and mas raise the objection that carbonate of lime, or Iceland spar, ced in gastric juice for some hours, becomes corroded and suffers a y notable diminution of weight, which can arise solely from the pres-

ence of a free acid. MM. Bernard and Barreswil likewise state some strong objections to the views of M. Blondlot in a paper published in 1844. They show that M. Blondlot failed to obtain effervescence by adding carbonate of lime to gastric juice, because he employed a too much diluted fluid; on concentrating the gastric juice a little, the effect was readily produced. Admitting that a free acid is present, they deny that it is hydrochloric acid, because that acid exists in the gastric fluid only in the state of chloride. If a minute quantity of oxalic acid be added to the gastric juice, a precipitation is occasioned by the formation of insoluble oxalate of lime, whilst an equal quantity of the same reagent, added to distilled water containing a two-thousandth part of hydrochloric acid, to which chloride of lime had been added, produced no such effect. The lime of the gastric juice unites with the oxalic acid; but that acid will not displace lime from its connection with hydrochloric acid. Nor is the acid of the gastric juice free acetic acid; the most delicate tests failed to detect it. MM. Bernard and Barreswil infer that there is in the gastric fluid a minute proportion of phosphoric acid, which, however, is not the only free acid. The lactic acid, according to these observers, is the principal acid of the gastric juice, because the behaviour of a fluid acidulated with that acid corresponds very exactly under chemical examination with that of the gastric juice. Thus the distillation of water acidulated with lactic acid exhibits exactly the same stages as that of the gastric fluid—first, there passes over only pure water, in the next stage an acid liquid, in which salts of silver do not throw down a precipitate, and there remains a strongly acid fluid effervescing with carbonates; in this, remaining liquid hydrochloric acid may be detected, if a minute quantity of chloride of sodium had been added to the fluid previous to distillation.

The acid of the gastric juice produces salts of zinc, lime, baryta, and copper, similar to those formed by lactic acid; and MM. Bernard and Barreswil affirm that it readily decomposes the chlorides in concentrated solutions. Hence it is that hydrochloric acid passes over in the last products of the distillation of the gastric juice.

These authors also state that the nature of the food appears to exercise no influence upon the nature of the acid, and that they have always found free lactic acid, whether after an exclusive vegetable or animal regimen continued for many days, or after a prolonged very sparing diet.

Dr. R. D. Thompson, of Glasgow, in a paper published in 1845, also disproves the opinion of Blondlot by experiment, and comes to the conclusion that the free acid of the stomach, in the digestion of vegetable matter at least, of all the known acids corresponds only with the lactic.

Lehmann attributes the acidity of the gastric fluid to both free hydrochloric and lactic acids. He obtained the former from the stomach of a diabetic patient, to whom he had administered an ipecacuanha emetic; and the latter from the stomach of a cat,

om which he was able to procure distinct crystals of lactate of zinc. n subsequent researches, Lehmann confirmed this conclusion respecting the nature of the acid of the gastric fluid.

Liebig lends his sanction to this doctrine, and especially to the iew put forward by Bernard and Barreswil, that both lactic and hosphoric acids exist in this fluid free, while there is no reason to eny the existence of an acid phosphate likewise. The opinion hat free lactic acid exists in the gastric fluid is not new. It was ut forward by Chevreul many years ago, and afterwards by Leuret nd Lassaigne. In 1823 our distinguished friend, Dr. Graves, of ublin, published analyses of the fluid of the stomach from two patients, in which he found free lactic acid in abundance. Notwithstanding what has been done on this subject, it must be confessed hat the full truth has scarcely yet been arrived at. We have yet o learn whether the constitution of the gastric juice is constant—whether the same acids or acidifying agents are present in all animals, and under all conditions of feeding and food; and we have lso to ascertain whether any and what changes may be produced y disease in the chemical characters of the gastric fluid. The inquiry taken up on a large scale among the lower animals, and extended to man, in health and disease, would, no doubt, yield most aluable and interesting results.

The digestive principle does not seem to be secreted in equal uantity or of equal power at all parts of the stomach. Meat and lbumen, digested with mucous membrane from the cardia, is by no eans so much acted upon as if digested with mucous membrane rom the pylorus or from the central part of the stomach. In the pig, here is a large patch of the membrane of a reddish hue, and of onsiderable thickness, forming that portion of the mucous membrane hich corresponds to the middle of the great curvature of the stomach; this, we find, exercises a more energetic action upon meat or lbumen than any other part.

It is highly interesting to notice that the mucus which accumulates upon the surface of the mucous membrane of the stomach has digesting power corresponding to that of the portion of mucous embrane from which it has been taken. This we have determined y our own experiments.

Nature of the Digesting Power of the Gastric Juice.—Having tated the leading facts which observation and experiment have developed respecting the act of digestion in the stomach, it remains o inquire what is the real nature of the digesting power of the astric fluid.

Two questions present themselves for consideration: is the digesting power of the stomach a true solvent power, producing simply *solution* of the matters submitted to its action, without effecting ny change in their chemical constitution? or does the digestive fluid xercise a catalytic action on the substances submitted to it, whereby it effects a *chemical decomposition* of them, similar to that produced in barley by diastase, whereby the starch of the grain is

converted into sugar, or like the action of yeast upon sugar, whereby the latter is decomposed into carbonic acid and alcohol?

To decide these questions, it is necessary to examine the exact nature of the changes produced in the food by stomach digestion.

Milk.—If milk be introduced into the stomach, its caseine is first coagulated and afterwards apparently dissolved. The solidified caseine seems gradually to melt down and becomes absorbed. In overfed infants, milk-curd appears in the stools in considerable quantity, the child having received so much milk that its stomach is unable to digest the caseine precipitated from it. When, however, the quantity of milk is in just proportion to the digestive power of the stomach, all the curd is digested, and therefore none is found in the stools.

Albumen.—White of egg (ovalbumen), if swallowed raw, is immediately coagulated by the gastric juice and then dissolved. Tiedemann and Gmelin found that, after three hours' sojourn in the stomach of a dog, albumen was dissolved, forming "a yellowish mucous liquor," which coagulated readily by heat.

Coagulated albumen becomes softened down and dissolved in the fluids of the stomach, from which it may again be precipitated by heat or nitric acid.

In experiments with the artificial digestive fluid, we find that if the fluid in which albumen had been digested be carefully filtered and subjected to heat and nitric acid, a copious precipitate of albumen will take place.

Meat is softened, gelatinized, and dissolved, and albumen may be precipitated by heat, nitric acid, or ferrocyanate of potass from the liquids obtained from the stomach.

Vegetable Substances.—In all the experiments upon animals of the carnivorous kind (cats, dogs), bread, potatoes, and other vegetable substances underwent change much more slowly than animal matters, and they became softened by admixture with the fluids of the stomach and appeared partially dissolved.

Boiled starch, in Tiedemann and Gmelin's experiments, underwent solution, and then did not exhibit its characteristic blue colour with iodine. In a dog, killed five hours after a meal of boiled starch, the contents of the stomach underwent no change of colour with iodine, but appeared charged with sugar and with a kind of gum of starch (*dextrine*). In another dog, similarly fed, and killed three hours afterwards, the starch which was dissolved did not react in the usual manner with iodine, but some portions not yet dissolved did exhibit the characteristic reactions. It would seem that immediately the starch becomes dissolved by the gastric fluid it loses its characteristic property of forming the blue iodide of starch.*

In the artificial digestion of starch, with the mucous membrane of the human stomach, we have not succeeded in producing any change in the starch: it still evinced its usual reaction with the iodine test.

* Tiedemann and Gmelin, Recherches sur la Digestion, par Jourdain, t. i. p. 349.

ıve, however, found that starch digested for some time in this volved a peculiar sour smell like that of cheese.

.chardat and Sandras report, respecting the influence of :h digestion upon starch, and upon amylaceous elements, differ- :rom Tiedemann and Gmelin. They state that they have been : to obtain any evidence of the conversion of starch into sugar; either by fermentation, nor by the polarizing apparatus of M. ıave they succeeded in procuring any indication of the exist- of sugar in the digested substances; and they were equally ›essful in detecting the formation of dextrine. Lactic acid, er, appeared to them to be formed in much larger quantity ı meal of starch than after one of fibrine or of gluten. These ers likewise state as the result of their experiments, that in ıman subject, and in the carnivora, feculent substances are :d with extreme slowness, and not at all unless the integument starch-grain have been ruptured by boiling.

ty or oily substances, as suet, fat, oil, butter, or wax, undergo .nge in the stomach, according to Bouchardat and Sandras, he lapse of some hours, and may be found in that organ un- :d, in the midst of other matters upon which the stomach ses a solvent action.

ı we have observed in our own experiments; and on perusing S. notes of the results of various experiments made thirty ago by Sir B. C. Brodie, and with great kindness placed at ›posal by him, we find the following statement: "When dogs ed on lard, the lard passed into the small intestine unchanged." 'ould seem to be the most reasonable conclusion which we can › from the preceding statements, that, in man and the car- , the fluid secreted by the stomach during digestion simply 'es animal and vegetable substances of the azotized kind, with- tering their chemical constitution, leaving amylaceous, oily, rine, and the allied substances but little or not at all acted

Chyme.—The mass that is contained in the stomach after .on has been going on for four or five hours, and which is com- known by the name of *chyme*, consists of aliments dissolved, éned and prepared for solution or other change by the gastric As they are mostly of the same kind, this mass presents a eneous appearance, except when substances are present which require a longer sojourn in the stomach or are only digestible ıe lower portion of the intestinal tube.

e of Stomach Digestion.—The process of stomach digestion is one. In the artificial digestions above referred to, it took ight to twelve hours to produce any marked effect upon the of meat and albumen submitted to the action of the digestive This, however, is much longer than the natural process. Ac- g to Dr. Beaumont's researches upon Alexis St. Martin, it ıree or four hours before the stomach became empty after a consisting chiefly of azotized food—and his tables show that ean time required for the digestion of the principal animal

substances in common use, such as butcher's meat, fowl, game, was from two hours and three-quarters to four hours.

In experiments on dogs, it has been found by most experimenters that no great advance in the solution of the contents of the stomach is made under from two to four hours. Gosse, who possessed the power of disgorging the contents of his stomach by previously swallowing a quantity of air, found that no change had taken place in the food after it had remained half an hour in the stomach: after the lapse of an hour he found the food much softened—but not reduced in weight: while, after two hours, it was not only much softened but considerably reduced in quantity, so that he could not return from his stomach more than half what he had taken.*

Purkinje and Pappenheim found, in their experiments upon artificial digestion, that, by gently shaking the tubes in which the process of digestion was going on, it became accelerated. This accords with what daily experience points out to us, namely, that agreeable and lively conversation during a meal, or gentle exercise after one, invariably promotes the primary stages of digestion.

Violent exercise after meals retards digestion, most probably by preventing the constant action of the gastric fluid upon the pieces of food in it—the movements of the body causing frequent change of place in the morsels of food.

The use of alcoholic stimulants also retards digestion, by coagulating the pepsine, and thereby interfering with its action. Were it not that wine and spirits are rapidly absorbed, the introduction of them into the stomach in any quantity would be a complete bar to the solution of the food, as the pepsine would be precipitated from solution as quickly as it was secreted by the stomach.

Absorption by the Stomach.—An important question, to which as yet we can give no certain reply, is as to what becomes of the food after it has been duly dissolved by the fluids of the stomach. When we find how completely albuminous and fibrinous substances are dissolved by digestion in the natural or artificial gastric fluid, it cannot be doubted that they are in a state fit for absorption while yet in the stomach, nor can there be any good reason to deny that a considerable quantity must be absorbed without passing further on in the alimentary canal. The great rapidity with which liquids of a simple and limpid kind, or the aqueous solutions of certain salts, as iodide of potassium, the alkaline carbonates, &c., find their way into the blood, denotes that this must take place very quickly after they have been swallowed, and that the bloodvessels of the stomach must be the principal channel through which they effect their entrance into the circulating system, and it scarcely admits of doubt that the dissolved aliments are removed through the same channels.†

The venous blood of the stomach passes to the vena portæ. Hence, matters absorbed by the sanguiferous system of the stomach

* Œuvres de Spallanzani, par Senebier, t. ii.

† We have detected iodine in the saliva and urine in twenty minutes after a solution of a few grains of iodide of potassium in a large quantity of water had been swallowed

ass by a very direct route to the liver, and probably excite that land to increased secretion for the purpose of digestion in the mall intestine.

The gastric fluid dissolves perfectly only the fibrinous and albumi-ous animal substances, and probably also the glutinous or azotized ortion of vegetable food; we must suppose, therefore, that it is only hese portions of the solid aliments which are absorbed by the sto-ach. Drinks, as water and various other liquids, fermented or not, re, doubtless, likewise in great part absorbed in the same way. ll other kinds of food, and such remaining portions of the azotized r liquid aliments as have escaped absorption by the stomach, after aving undergone to a certain extent maceration in it, are pushed awards into other parts of the digestive tube, there to undergo fur-her changes to fit them for being absorbed.

Eructation and Vomiting.—As there can be no doubt that the ovements of the stomach are capable of pushing on the food to-ards the intestinal canal, it appears *prima facie* extremely proba-le that the same muscular force may cause it to evacuate its contents hrough the œsophagus, if there be any obstacle to their downward assage, too strong to be overcome.* The muscular coat of the tomach, pressing by its passive contraction upon its contents, will ause them to pass in that direction which offers the least resistance. ow, in a state of health, the food, in order to return by the œso-hagus, must not only overcome the passive contraction of the mus-ular coat of that tube, but it must also ascend against gravity. foreover, the action of the fibres of the splenic extremity of the tomach favours the passage of the food toward the pylorus. Hence, ot only is there least resistance at the pylorus, but there is likewise *vis à tergo*, which favours the propulsion of the food in that direc-ion.

When, however, air accumulates at the cardia in such quantity as o distend that portion of the stomach, it opens the œsophagus by ts expansile force, and from its lightness rushes up the œsophagus, arrying with it sometimes liquid or solid food. When air is gene-ated in large quantity and with great rapidity, it is wonderful how uch may escape in this way, and large quantities of food may be ischarged from the stomach at the same time, solely by the con-ective force of the large bubbles of air ascending from it. This is *ructation*—it seems due solely to the presence of a large quantity f air in the stomach.

Vomiting is an act of a more complex character than eructation; y it solids and liquids may be expelled from the stomach through he œsophagus, even contrary to gravity. We must assume that a ecessary condition for the production of the act of vomiting is the xistence of obstruction at or near the pyloric portion of the stomach, which prevents or opposes the passage of the gastric contents in that

* The old and still prevalent notion of an inversion in the action of the stomach is ost probably erroneous. The inversion is only apparent, not real. See an able paper y Dr. Brinton on this subject.—*Lond. Med. Gazette*, 1849.

direction. Probably the whole of the pyloric third of the stomach is strongly contracted under the circumstances which ordinarily give rise to vomiting; and the contents of the viscus having been accumulated in its cardiac two-thirds, are thus brought into more immediate and direct communication with the œsophagus. The pylorus being closed against them, the stomach contents are forced through the œsophagus, not only by the muscular contraction of the stomach itself, but also by that of the abdominal muscles and the diaphragm.*

It is probable that where a very complete obstruction exists at or near the pylorus, as in cases of hernia and other mechanical obstacles, the act of vomiting partakes much of the nature of an overflow, and requires no more than the action of the muscular coat of the stomach itself. The slight effort which accompanies the discharge of the stomach's contents in cases of this description, denotes this. But when vomiting is caused by an emetic, or is the result of sea-sickness, or of nervous irritation, as in stimulation of the fauces, or in brain disease, an active and almost convulsive contraction of the diaphragm and abdominal muscles accompanies it, and, no doubt, constitutes the principal expelling force. These muscles, by their simultaneous forcible contraction, form two plane surfaces, one passing downwards and backwards, the other nearly vertically downwards, which are approximated very closely to each other, and compressing the stomach between them, cause the forcible ejection of its contents in that direction, which offers least or no resistance, namely, through the œsophagus.

The act of vomiting is ushered in by a deep inspiration, during which the diaphragm is firmly contracted. Just at this moment the abdominal muscles contract forcibly and almost convulsively. Thus an effort at expiration, in which, doubtless, other muscles take part, besides those of the abdominal walls, quickly succeeds the act of inspiration. But the diaphragm does not become relaxed as in ordinary expiratory efforts, because the air is only very partially and slowly expelled. For, at the same time that the abdominal muscles and the diaphragm are thrown into contraction, those of the glottis are exerted to a like convulsive action, and maintain a partially closed state of the glottis which resists the expulsion of air from the lungs and keeps them in a certain state of distension until the effort of vomiting is over, when the diaphragm relaxes and complete expiration takes place. That there cannot be complete closure of the glottis in the effort of vomiting, is shown by the fact that that act is very frequently accompanied by a loud explosive noise, which must be formed in an open, although a resisting glottis.

Dr. Anderson has shown by direct experiment that when dogs vomit under the influence of tartar emetic, the diaphragm is forcibly contracted. He introduced his finger into the abdomen, and found that during each effort of vomiting the diaphragm became tense

* The power of returning portions of the food at will (*rumination*), which some men have acquired, is effected by a strong voluntary contraction of the pyloric muscle, and by expulsive efforts operating directly on the cardia portion of the stomach, which can thus expel its contents only in the upward direction.

and rigid, and descended towards the abdomen. And this he found took place even when the trachea had been previously opened; whence we may infer that the force of the expiratory muscles is spent chiefly upon the stomach.*

A warm controversy took place in the last century, and was revived in the present, with reference to the share which the stomach itself takes in the act of vomiting. Many high names in physiology took part in this discussion, some maintaining, among whom was John Hunter, and subsequently, Magendie, that the stomach was perfectly passive, and that the abdominal muscles and the diaphragm were the sole agents of expulsion; while others, as Haller, Rudolphi, &c., allowed that the contractions of these muscles only assist the expulsive efforts of the stomach, which, in some instances, may act independently of the surrounding muscles. Maingault affirmed that he had seen vomiting occur after the division of the diaphragm and the abdominal muscles, and Rudolphi made the same assertion. And the Committee of the French Academy appointed to investigate the question, admitted that it needed only a very slight external pressure to produce vomiting, and that distinct contractions of the muscular coat of the stomach were seen during the act in the neighbourhood of the pylorus. The question is one which cannot be decided by cruel experiments, unless it can be shown in several instances that vomiting can take place under conditions which render the abdominal muscles and diaphragm incapable of acting; such evidence would unequivocally demonstrate the activity of the stomach.† But the opposite experiments, such as the non-occurrence of vomiting when the abdominal muscles and diaphragm have been paralyzed, or its occurrence when an inert bag, as a pig's bladder, has been substituted for the stomach, the external muscles being intact (as in Magendie's noted but most cruel experiment), lead to no conclusion, for, in the one case, the violence done so impairs the conditions necessary for the act (both nervous and muscular) that it cannot be expected to take place; and in the other, the substitution of the inert bag, and the section of the œsophagus, are favourable to the escape of fluids from the former and through the latter, under the slightest pressure.

The nervous changes which take place in the act of vomiting are of the most interesting kind. It must be borne in mind that this act may take place—1, from the introduction of certain substances into the stomach, some of which, as bile, mustard, common salt, not becoming absorbed, must act simply by the impression they make on the mucous membrane; 2, by the introduction of emetics, as tartar emetic, into the blood, or by the presence of certain morbid poisons

* See Anderson, Lond. and Edin. Monthly Journal, 1844. In this paper, Dr. Anderson has given a complete refutation of Dr. Marshall Hall's supposition that the diaphragm is inactive in vomiting.

† M. L'Epione records, in the Bulletin de l'Académie de Médecine, a case in point. A man's abdomen was torn open by a horn, and the stomach wholly protruded. For half an hour it was seen repeatedly and forcibly contracting itself, till, by its own efforts, it expelled all its contents except the gases.—See Paget's Report for 1845.

in that fluid; 3, by mental emotion, as that excited by the sight of a disgusting object; 4, by irritation at the base of the brain. Vomiting may be caused, therefore, either by the direct application of a stimulus to the gastric surface, or by the disturbance of some part of the brain through the presence of particular substances in the blood, that is, by causes operating from periphery to centre, or by causes acting directly on the centre itself. Either the disturbing cause, as tartar emetic in the blood, affects the medulla oblongata, in which are implanted the vagi nerves; or some of the fibres of these nerves propagate to the centre the effects of the peripheral irritation at the gastric mucous membrane. When the medulla oblongata is thrown into excitement by any of the causes above mentioned, certain motor nerves implanted in it are stimulated to action, and the abdominal muscles, the diaphragm, and the muscles of the larynx as well as the muscular fibres of the stomach and œsophagus, are thrown into that combined action which is essential to the production of active vomiting.

When vomiting is the result of a peripheral stimulation, it affords a remarkable example of a reflex or physical nervous action of the most complex kind, in which, from the excitation of a few sentient nerves, the nervous force is made to radiate upon several muscles and to excite to simultaneous and combined action some which usually antagonize each other, and are, therefore, never, excepting in this act, in the same condition at the same time. We allude to the abdominal muscles and the diaphragm; the former as muscles of expiration being the habitual antagonists of the latter, which is the great muscle of inspiration. In short, the excitation of the nervous centre, which is sufficient to cause vomiting, gives rise to a forcible act of respiration, in which the act of expiration is so powerfully opposed by the contracted state of the constrictors of the larynx, the diaphragm also remaining in strong contraction, that the main force of the expiratory muscles is directed to compress the stomach against the latter muscle.

On the subjects of this chapter, see the various works on Anatomy, and the principal systems of Physiology previously referred to: Œuvres de Spallanzani; Tiedemann et Gmelin sur la Digestion; Hunter's Animal Œconomy, by Owen; Eberle, Physiologie der Verdauung, 1834; Simon's Chemistry, by Day; Dumas, Traité de Chimie, tom. viii. (1846); Beaumont on Digestion; Blondlot sur la Digestion; Dr. Kirkes's excellent Manual of Physiology; Bouchardat and Sandras, Comptes Rendus for 1841. Bernard and Barreswil, Comptes Rendus, 1844; Dr. R. D. Thompson, Lond. Med. Gaz. 1845.

CHAPTER XXV.

NTESTINAL DIGESTION.—ANATOMY OF THE INTESTINAL CANAL IN IN AND VERTEBRATA.—THE MUCOUS MEMBRANE OF THE INTES-NE.—ITS FOLDS AND VILLI.—ITS GLANDS.—DIGESTION IN THE IALL INTESTINE.—FLUIDS POURED INTO THE SMALL INTESTINE.—IE PANCREATIC FLUID.—THE BILE.—THEIR INFLUENCE.—DIGES-ON IN THE LARGE INTESTINE.—DEFECATION.

natomy of the Intestinal Canal.—The intestinal canal com-ces at the pylorus and terminates at the anus. It exhibits a obvious subdivision into two portions: a narrower and much er portion, disposed in numerous coils or convolutions, which is d *the small intestine* (intestinum tenue); and a much wider but ter portion, *the large intestine* (intestinum crassum). The length e whole intestinal canal in the adult is between thirty and forty or about six times that of the body: the small intestine forms sixths of this.

here is a very distinct natural demarcation between these two ions of the intestinal canal; the large intestine commences by lated *cul-de-sac*, which communicates on its inner side with the ll intestine. This portion, which is the widest part of the large stine, is lodged in the right iliac fossa; it constitutes the com-cement or the head of the colon, and as it forms a blind extrem-or *cul-de-sac* beyond the junction of the small intestine with t is named *caput cæcum coli*, or commonly *cæcum*. Connected it is a remarkable appendix, which proceeds from its inner and erior part, and hangs down into the pelvis in a slightly curved l, which gives it the appearance of a worm (lumbricus), and re-ing support from a small fold of peritoneum. This is called the *endix cæci vermiformis.* It is a small process from the cæcum, ow, cylindrical, in size rather larger than a goose-quill, about e inches long, and ending in a blind extremity which lies free in pelvis, but having a free communication with the cæcum where attached to that intestine. The large intestine commencing at part ascends from the right iliac fossa, through the right lumbar on, as high as the concave surface of the liver; this forms the *t* or *ascending colon;* at the liver it turns to the left and passes, n arched form, across the abdomen from the right to the left ochondrium, thus forming *the transverse colon*, or *the arch of the s;* it then turns downward, passes through the left lumbar re-to the left iliac fossa; this portion, which is straight, or nearly s the *left* or *descending colon.* In the left iliac fossa the intes-becomes somewhat curved, and is rather loosely attached to the of the pelvis; its curve resembles the letter S; this portion, inates in the pelvis, and is named *the sigmoid flexure of the*

colon; lastly, this becomes continuous with the pelvic or terminal portion of the intestine, which, although far from being straight, is designated *intestinum rectum*, or commonly *the rectum*. This opens externally at the *anus*, its mucous membrane becoming continuous with the skin at that orifice.

The small intestine is arranged in many convolutions, and, with the exception of its upper portion, *the duodenum*, it is quite loose in the cavity of the abdomen, and even in that of the pelvis, occupying the central part of those cavities. The large intestine or colon embraces it on the right, above, and on the left. Three portions of the small intestine have always been recognized by anatomists, which, although not distinguished by any well-marked external boundaries, exhibit in their mucous membrane features (to be pointed out hereafter) which form their most appropriate means of distinction. The upper portion is sufficiently distinct from the rest by its dilated form, its horseshoe curve, and by being closely fixed to the spine, in the greatest part of its extent, by peritoneum. This is *the duodenum:* it forms about the first twelve inches of the small intestine.

The middle portion of the small intestine is the *jejunum*, and the terminal portion is the *ileum*. These have no external mark to distinguish the one from the other. The jejunum is wider than the ileum, and its coats are thicker; the intestine tapers as it approaches the cæcum.

The whole intestinal tube is more or less completely covered by the serous membrane of the abdomen, *the peritoneum*. The duodenum above and the rectum below are least covered by it; the rest is almost entirely enveloped, a small portion being left uncovered where the bloodvessels enter the intestine, and where the peritoneum passes to the abdominal wall. Each portion of intestine is attached to the abdominal wall by a process of peritoneum, the duodenum and the rectum very closely, the rest more or less loosely. The process of peritoneum which connects the small intestine to the spine is *the mesentery*, and each portion of the large intestine is connected to the corresponding region of the abdominal wall by a process of peritoneum, which is designated by prefixing the word *meso* (μέσος medius) to the name of the particular portion of intestine: thus *meso-cæcum* is the process which connects the cæcum to the iliac fossa: *mesocolon*, right, transverse, left, is that which belongs respectively to the three portions of the colon; and the *mesorectum* connects the rectum to the concavity of the sacrum.

Attached to the colon are small processes of peritoneum, containing fat, and called *appendices epiploicæ*, from their resemblance to the *epiploon*, or great omentum, which descends from the great curvature of the stomach and from the transverse colon, like a curtain, in front of the small intestine.

The Intestinal Canal in Vertebrata.—The intestinal canal is disposed in the four vertebrate classes much on the same plan as in the human subject:—

In *Fishes*, the intestinal canal exhibits for the most part a very simple conformation. In many fishes it passes quite straight, or very nearly so, through the body: when it

exhibit convolutions they are few and short, and rarely to any great extent. A ic valve is generally present, separating the intestine from the stomach; imme- ly succeeding to this valve, the intestine generally experiences a dilatation, whence adually contracts to its terminal portion, which again becomes dilated. This on corresponds to the large intestine, and commonly a valvular fold of the mucous brane is present at its union with the preceding portion; it terminates in a cloaca non to it with the genital and urinary organs. In some fishes, however, no dila- n is found, nor any external distinction between the stomach and intestine, and anal from the œsophagus to the anus is of uniform caliber. Immediately below yloris we very commonly find a series of tubular prolongations from the intestine, inating in blind extremities. These constitute the *appendices pyloricæ*, or pyloric les, which most comparative anatomists consider to supply the place of a paren- atous pancreas. These appendices vary considerably in both number and size. *uronectes flesus* there are only two very short ones, placed opposite each other at ent sides of the intestine;* in *ammodytes tobianus* there is only one; in *Blennius* and *rosteus* there are only two, so small that Wagner compares them to the follicles e proventriculus of birds; there are from ten to thirty in many species of *Clupea* *Salmo*, and in the genera *Gadus* and *Scomber* (the common mackerel, for example), are as many as two hundred.† On the other hand, they are entirely absent ny fishes. Again, in some they are simple, in others they become subdivided or hed at their blind extremities, and in others still these branches undergo subdi- n, and the resemblance to the glandular formation is enhanced by the fact that branchings are connected by means of cellular membrane and bloodvessels.

Reptiles, the intestinal canal differs from that in fishes chiefly in having under- a slight increase of development. The division into large and small intestine is ct throughout the class, and often an ileo-cæcal valve is present. In *Ophidia*, mall intestine presents numerous short convolutions at acute angles; the large tine ends in a cloaca. The intestinal canal is longest in the *Chelonia*, and next em in the *Crocodiles*. In the *Chelonia*, the line of distinction between the and small intestine is not so distinct as in the rest, and the muscular coat is rkable for its great thickness. The tortoises have a short, wide, and cylindrical m, which is continuous without interruption with the large intestine: they have circular ileo-cæcal valve.‡ The great thickness of the muscular coat, and the st total obliteration of the canal during its contracted state, constitute one of the striking peculiarities of the intestine in Chelonian reptiles. In *Batrachia*, the ence between large and small intestine is very distinct, being chiefly indicated by ence of caliber, and in frogs a circular ileo-cæcal valve; in the toad, however, is a small cæcum, without an ileo-cæcal valve. In most of the *Saurian* reptiles there æcum, according to Meckel, and generally an ileo-cæcal valve: in the Crocodile alve is present but the cæcum absent.

Birds, the intestinal canal, although longer than either in fishes or reptiles, yet s considerable simplicity of form. It presents much variety in length and in the er of its convolutions, according to the food and habits of the bird. The duode- which immediately follows the gizzard, has always the form of a long fold, which ins the pancreas in it. The small intestine, more or less folded in different orders, nates in a short and somewhat wide large intestine, at the commencement of are two cæca, one on each side of the intestine. These cæca vary considerably gth from almost simple papillæform offsets, as in the Soland goose,§ to processes feet in length, as in the grouse. It sometimes occurs that there is only one m. The large intestine is short and straight, and is continued from the termina- f the small intestine, without fold, to the cloaca. There is connected with the intestine an appendage, the remains of the duct of communication between the bag and intestine in the chick. In some birds this appendage, which is said to void of a muscular tunic, is as large or larger than the cæca.

much diversity exists in the form, length, and arrangement of the intestinal canal e different orders of Mammalia, that it will be necessary briefly to state its pecu- ies in each order.

Carnivora, we find examples in which the intestinal canal is remarkably short in ion to the length of the body. The small intestine has but few and simple con- ions: it opens into a short cæcum (convoluted, however, in the dogs), which ely differs in width from the rest of the large intestine. The proportion in the h of the intestinal canal to that of the body varies from, according to Meckel, five

* Figured in Carus's Anat. Comp. pl. ix. Fig. 20.

† R. Wagner, Vergleichend. Anatom.

‡ Meckel. § Sir E. Home's Comp. Anat. pl. civ.

to one, as in the cats and dogs; to eight to one, and nine to one, as in the hyena and bear; or to fifteen to one, as ascertained by Meckel, in *Phoca vitalina*. The large intestine is shorter and wider than the small; it is cylindrical in form, not sacculated, as in man and many others.

In *Insectivora*, the intestinal canal is short, and without cæcum, the diameter being pretty uniform throughout. In *Sorex*, according to Meckel, its length is to that of the body as three to one, in the hedgehog as six to one; in a mole examined by ourselves, which measured from snout to tail seven inches, the intestinal canal, from pylorus to anus, measured four feet three inches.

In the *Cheiroptera*, a very marked distinction exists in the form of the intestinal canal between the frugivorous and insectivorous genera. In the former, as in *Pteropus*, it presents numerous coils, and is in length seven times that of the body—the cæcum is absent. In the latter, the canal is extremely short, bearing to the length of the body the proportion of two or three to one as in *Vespertilio noctula*. Much variety exists as regards both the form and length of the intestinal canal in the *Edentata*. The distinction between large and small intestine is not evident in many of the genera. In the *Manis* and *Bradypus* there is no trace of a cæcum; on the other hand, the two-toed ant-eater (*Myrmecophaga didactyla*) has, according to Daubenton and Meckel, two small and narrow cæcal appendages resembling those of birds, situated at the confines of the two portions of the intestine; the orifices of these cæca are so small that the fecal matter cannot find its way into them. Mr. Owen has preserved, in the Hunterian collection, a specimen from the weazel-headed armadillo (*Dasypus mustelinus*), of two similar cæca between which the ileum terminates. The terminal aperture of this intestine is of a slit-like form, and from its position between the cæca it admits of being effectually closed by the lateral pressure of the contents of the cæca.*

Great length and wide caliber are the characteristics of the intestinal canal in *Ruminants*, *Solipeds*, and *Pachydermata*. In the sheep, which belongs to the ruminant order, the intestine is in length thirty times that of the body, and in the horse, according to a measurement made by us, the intestinal canal was eighty-seven and a half feet in length. There are numerous convolutions of the small intestines in each of these orders, and a large capacious cæcum, from which the wide and convoluted colon is continued. In *Ruminants*, neither the cæcum nor the colon is sacculated by longitudinal bands, whilst both the *Solipeds* and *Pachydermata* exhibit the sacculated character in a very marked degree, and the bands of longitudinal muscular fibres are very highly developed, extending from the blind extremity of the cæcum to the rectum. There is no ileo-cæcal valve, properly so called, in these orders, but the passage from the ileum to the cæcum (a foot and a half long in the horse) is very much contracted, and its inner membrane thrown into six or eight thick longitudinal folds, which are closely applied to each other and keep the canal closed. The cæcum in each of the orders is very capacious; in the *Ruminants*, the capacity of this portion of intestine somewhat exceeds that of the fourth stomach, according to Meckel. In the *Solipeds*, the cæcum is still more capacious. Meckel asserts that it is capable of containing more than three times as much liquid as the stomach. In *Pachydermata*, the cæcum is shorter and wider than in the other orders; it is, according to Meckel, less capacious than the stomach.†

The *Rodentia* have, in general, a very long and convoluted intestinal canal. The small intestine has a mesentery of considerable length; its caliber is small and pretty uniform throughout, being however largest superiorly. In most of the *Rodent* genera the cæcum is of very great size, and in some it occupies a large portion of the abdominal cavity; in the omnivorous rodents, however, as the rat, the cæcum is of small dimensions. The whole large intestine is cellulated, the cells being formed by longitudinal fibres and circular constricting ones.

In the genus *Myoxus* (dormouse), the cæcum is entirely absent, the only exception according to Meckel, to the presence of this cavity in the rodent order.

In the *Marsupiate* animals, the distinction between large and small intestine is clearly marked by the presence of a cæcum. The small intestine is long, and in some very wide; the cæcum is of moderate length and width, its capacity being much below that of the stomach.

The chief peculiarity of the intestinal canal, in the *Monotremata*, is to be found at its inferior extremity, where a cloaca exists common to the rectum with the urino-genital organs. A small cæcum separates the long and small intestine.

* Catalogue of the Hunterian Museum, vol. i. pp. 219, 729, A.

† See Sir E. Home's plates of the cæca of several mammiferous animals, plates cxii. et seq. vol. ii.

The *Cetaceous* mammalia have an intestinal canal of considerable length. The length of the canal in the zoophagous cetacea is to that of the body as eleven or twelve to one. (Meckel.) According to Cuvier, the proper whales have no division between large and small intestine, and consequently no cæcum. This is the case in the porpoise. In the *Balæna Rostrata*, however, according to Hunter, and in all the *Balænæ*, according to Cuvier, a small cæcum, not unlike that of carnivora, exists. In the herbivorous cetacea, the intestinal canal is of proportionally greater length than in the zoophagous cetacea. In the *dugong*, according to Meckel, its length exceeds forty times, and in the *lamantin* of Kamtschatka, twenty times that of the body.

The *Quadrumana*. The length of the intestinal canal in this large order of Mammifera presents very remarkable variety, which is the more curious as the nature of the food is, with few exceptions, similar in the various genera. The proportion of the length of the intestinal canal to that of the body is in some as eight to one, whilst in others it is only as three to one.* The division into two portions is effected in the same manner as in the human subject, and the general arrangement of both small and large intestine is very similar to those of man. A cæcum exists in all the genera, but presents considerable variety as to length: an increased length of this portion of intestine along with a larger development of the splenic extremity of the stomach being employed in some cases to compensate for a deficiency in the length of the intestinal canal. The orangs and gibbons have the peculiarity, which they alone possess in common with man, of a process from the cæcum, some inches in length, denominated *the vermiform appendix.*

From the preceding brief review of the anatomical characters of the intestinal canal in the vertebrate classes, we gather, that this portion of the digestive tube diminishes in complexity as we descend from mammalia to fishes: that a short and simple intestinal canal is generally coexistent with a diet of animal food; and, on the other hand, that a diet of vegetable food, or a conjoint animal and vegetable diet requires greater length and greater complexity in the form and structure of the intestines. In estimating the length of the intestinal canal we must not confine our examination to a mere external measurement, as we should thereby be led to a very erroneous conclusion. Deficiency in length, as measured on the exterior of the intestine, may be supplied by increased width—by a more highly-developed state of the villi of the mucous membrane—by numerous folds of that membrane; and the energy of the action of the mucous membrane on the contents of the intestine, may be augmented by the greater number and size of the glands which pour out their secretions on its surface. It may further be observed, that as the several portions, whether of small or large intestine, have very definite characters as regards the mucous membrane, we can readily determine the relative length and development of each portion, and thus deduce its proper degree of importance in intestinal digestion. But upon these points it is much to be regretted that we are greatly in want of precise information; we are persuaded that nothing would tend more to the correct determination of the office performed by each portion of the intestinal canal than a series of careful observations with special reference to anatomical characters on the intestines of a great number of animals.

Much importance is attached by Physiologists, and apparently with good reason, to the size and form of the cæcum. It is difficult, however, and in the present state of our knowledge impossible to determine the law which influences its development. Nevertheless, it may be stated that there appears to be a direct relation between this development of the intestine and the hardness of digestion of the food: in some instances we find that a large cæcum compensates for a less capacious stomach, as in the *Solipeds*, and in these cases there exists even a striking similarity in the forms of those two organs. A large cæcum, then, belongs to the herbivorous classes, as a large stomach does, and a small cæcum would, on the other hand, indicate a diet of animal food. Anatomy would seem to point to the conclusion that the function of the cæcum is not dissimilar to that of the stomach, and that in it substances hard of digestion are subjected a second time to a reducing action resembling that of the stomach. Perhaps the anomaly which we have noticed in the dormouse, in the absence of a cæcum, may be explained on the supposition that this accessory digestive cavity was rendered unnecessary in consequence of the existence of the glandular pouch at the cardiac orifice of the stomach in that animal.

The subdivision of the intestinal canal, in man, into the small and large intestine, by the difference in caliber of those two portions of

* *Vide* a table in Meckel's Anat. Comp. (French ed.) tom. viii. p. 778.

that tube, as well as by the existence of an ileo-cæcal valve, has already been described. There are other characteristics, however, of anatomical constitution which likewise sufficiently distinguish them. The whole of the intestinal tube is composed of certain tunics, which, enumerated from within outwards, are as follows: 1, the mucous membrane; 2, the submucous tissue; 3, the muscular coat; 4, the serous coat, which is connected to the tunic last named by a thin layer of very delicate areolar tissue. Of these tunics, the mucous membrane, the muscular coat, and the serous coat, exhibit, on the whole, very distinctive characters in the two divisions of the intestine.

The mucous membrane continuous with that of the stomach exhibits very characteristic features in the different portions of the intestine. We shall reserve the description of it until we have spoken of the other tunics.

The submucous tunic is a layer of very fine areolar tissue, which connects the mucous to the muscular coat; it is entirely devoid of fat, and presents the same characters throughout the whole intestinal canal. Placed immediately underneath the mucous membrane, it constitutes the medium, through which the various sanguiferous and other vessels and the nerves pass to that membrane.

The muscular coat of the small intestine consists of two layers or planes, which differ from each other as regards the direction of their fibres. The external plane is composed of longitudinal fibres, continuous superiorly with the longitudinal fibres of the stomach; they form a continuous tunic surrounding the intestine, and extending from the pylorus to the cæcum. C. B. Albinus* states that they exist only as a band a finger-breadth broad, and corresponding to the concave border of the intestine, along which the mesentery is attached, and to this he attributes the concavity which the inflated intestine presents towards the mesentery. We have no doubt, however, that the longitudinal fibres form a continuous tunic around the intestine, though they are strongest along the line of attachment of the mesentery, and are very apparent in that situation, at times when they are indistinct elsewhere. The circular fibres are much more distinct than the longitudinal; the direction of which they cut at right angles. They surround the intestine in a circular manner, not spirally, as some anatomists have asserted.

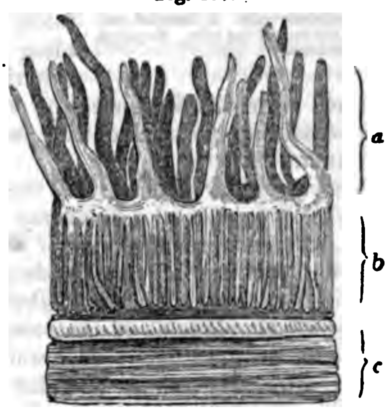
The muscular tunic of the large intestine is likewise disposed in two layers of fibres. The external, however, does not, as in the small intestine, form a uniform layer round the intestine, but is developed chiefly in three bands, about half an inch wide, with a few intervening longitudinal fibres. These bands commence at the root of the vermiform appendix of the cæcum, and extend in this form to the rectum, where they become expanded, and form a continuous tunic over the whole intestine. The longitudinal bands are shorter than the intestine; the effect of this is, to produce a puck-

* Specimen Anatomicum exhibens novam tenuium Hominis Intestinorum Descriptionem. Lugd. Bat. 1724.

of all its coats at certain intervals throughout the whole of the colon. At these points the colon appears to be cond, as by a shorter bundle of circular fibres, and its mucous rane projects into the interior, forming large folds. These separate sacculated portions of the intestine, which are the f the colon, and the convex bulgings seen on the exterior of flated large intestine are the walls of these cells. The circures are arranged in the same manner as in the small intestine, spread uniformly over the surface of the intestine.

the Mucous Membrane of the Intestinal Canal.—The intestiucous membrane so far resembles that of the stomach, that it the *compound* variety (see *ante*, p. 546); and its thickness is l by the involution of multitudes of tubes, which terminate in closed extremities, and rest vertically upon the submucous tis- Most of the tubes remain undivided from their open to their . extremities, some are bifurcated towards the blind extremity. tube has a separate orifice on the free surface of the mucous rane, except in the upper part of the duodenum, and in the a, where they open by sets of three or more on the floors of w cells, as in the stomach. These tubes are commonly called rkühn's *follicles;* but they were first described by Brunn, or ıer, who has given a good delineation of them; and their real e was not known to Lieberkühn, who regarded them as muscles. examining thin vertical sections of the mucous membrane from art of the intestine, we see tubes closely set parallel h other; they are straight, excepting that here and one is bifurcated, they exno irregularity or bulging eir walls, and are pretty rm in diameter throughout length (Fig. 157). All the nts of the mucous mem- contribute to their formathe basement-membrane, pithelium, and the submutissue, which is sparingly posed between them.

Fig. 157.



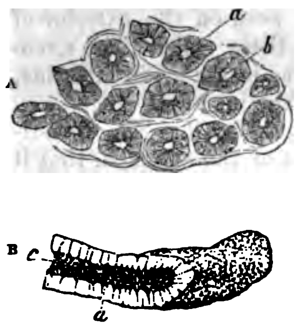
Section of the mucous membrane of the small intestine in the dog, showing Lieberkühn's follicles and villi.
a. Villi. *b.* Lieberkühn's follicles. *c.* Other coats of the intestine.

e epithelium is columnar or lumnar; the cells are disl in a single layer, with one adherent to the basementrane. The cast-off partioften fill each tube as muwhich escapes at the orifice, on the free surface of the mucous brane. These tubes are shorter in the large than in the small tine; and as the thickness of the mucous membrane is deent on their length, we find it less thick in the former than in

the latter intestine. The mucous membrane is thickest where the tubes are most developed, namely, in the jejunum.

Lieberkühn's follicles are doubtless secreting agents, resembling in that respect the tubes of the stomach. Probably their office, in reference to the intestinal contents, is the same throughout the whole intestinal tube, as they present everywhere so much uniformity of arrangement and structure, and as each portion of the intestine possesses other and peculiar glands. As yet, however, nothing is known respecting the nature of the mucus which is secreted by them.

Fig. 158.



A. Transverse section of Lieberkühn's tubes or follicles, showing the basement-membrane and subcolumnar epithelium of their walls, with the areolar tissue which connects the tubes. *a*. Basement-membrane and epithelium, constituting the wall of the tube. *b*. Cavity or lumen of the tube. Magnified 200 diameters.

B. A single Lieberkühn's tube, highly magnified. A happy accidental section in the oblique direction has served to display very distinctly the form and mode of packing of the epithelial particles, the cavity of the tube, and the mosaic pavement of its exterior. *a*. Basement-membrane. *c*. Internal surface of the wall of the tube. Magnified 200 diameters.

By the infinite multitude of minute and microscopic involutions which form Lieberkühn's follicles, the extent of surface of the mucous membrane is enormously increased. It is still further enlarged by the existence of various folds and processes, which project into the cavity of the intestine; these we shall now proceed to describe.

Of the Valvulæ Conniventes, Folds, and Villi.—The mucous membrane of the small intestine exhibits numerous folds, which, small, irregular, and resembling the rugæ of the stomach in the superior third of the duodenum, assume a much more definite form, and are much more highly developed in the remaining portions of the small intestine, but especially in the jejunum.

The irregular foldings of the upper portion of the duodenum very soon exhibit the tendency to assume a transverse direction with reference to the axis of the intestine. In the middle and inferior portions of the duodenum we find numerous transverse plaitings or folds, from one-eighth to a quarter of an inch in depth. These are simple folds of the compound mucous membrane, including a process of the submucous areolar tissue: they are called *valvulæ conniventes*, from their valvular form, and from their movements under water resembling the flapping of valves, or the winking motion of the eyelids. Each fold passes round the intestine for about three-fourths or five-sixths of its circumference, gradually diminishing in depth towards each extremity, but sometimes bifurcating and coalescing by one or both subdivisions, with the fold above and below. In the lowest part of the duodenum, and in the jejunum, the *valvulæ conniventes* acquire their highest development. Here they lie very close together, and many of them pass nearly round the intestine; they are deeper, also, here than elsewhere,

eing sometimes half or three-fourths of an inch in depth. In the eum they gradually diminish in length and in depth, frequently ot passing round more than one-half the circumference of the itestine, and measuring not more than one-fourth or one-eighth of n inch in depth; and in the lowest part of the ileum they almost ntirely disappear.

It is remarkable that these folds are peculiar to the human subject. No other animal, so far as we know, exhibits any arrangement of transverse folds of the intestinal mucous membrane resembling them.

The folds of mucous membrane in the large intestine are the artitions between the cells of the colon; they exhibit much uniormity of shape, although they vary very much in size; they are ast developed in the sigmoid flexure.

At the junction of the ileum with the cæcum, there are two folds hich bound the slit-like aperture of communication between the nall and the large intestine. These are the segments of the *ileoecal valve.* The aperture is a simple slit, which passes nearly horiontally from before backwards, and is bounded on all sides by nucous membrane. Its lower border is formed by the free edge of deep semilunar fold of mucous membrane, inclosing submucous ssue, and a few circular muscular fibres; and another fold, of nuch less depth, but of similar shape and constitution, form its pper lip. This latter fold has a more horizontal direction than the ormer, which is nearly vertical. The folds coalesce in front of and ehind the aperture, and form small bands, called *fræna*, and which ollow for a short distance the course and direction of the segments f the valve. The free margins of these two segments come in aposition in the distended state of the cæcum, and close the aperture, r at least diminish and constrict it so much as, in general, to preent the reflux of any but liquid or much-subdivided matters into the nall intestine.

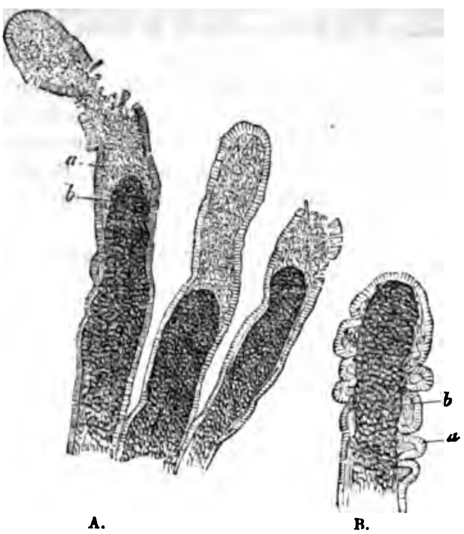
In the rectum, there are folds of various sizes and directions, hich are most numerous in the empty state of the gut, and are ffaced by its distension. The late Mr. Houston, of Dublin, has escribed certain permanent folds, or valves, of semilunar shape, hich he demonstrated by moderately distending the rectum with lcohol, which, at the same time, hardens its tunics, and thus dislays their condition in the state of repletion. Three is the average umber; but sometimes a fourth is found, and at other times only wo are present. The largest and most constant valve is situated pposite the base of the bladder, about three inches from the anus. he fold next in frequency is placed at the upper end of the rectum; nd the third occupies a position midway between these. When a ourth is present, it is situated about one inch above the anus. In he empty state of the intestine, these folds overlap each other, s Mr. Houston remarks, so effectually as to require considerable nanœuvring to conduct a bougie or the finger along the cavity of he intestine. Their use seems to be "to support the weight of

fecal matter, and prevent its urging towards the anus, where its presence always excites a sensation demanding its discharge."*

Of the Villi.—Villi are minute processes of the mucous membrane of the small intestine, to which they are exclusively confined (Fig. 159). They project from the free surface of the mucous membrane into the cavity of the intestines, and seem admirably adapted to become implanted, like so many little roots, in any semifluid or fluid material which may fill the bowel. Villi are first found in the duodenum, where they appear to develop themselves as elongations of the partitions between the cells into which Lieberkühn's tubes open. In the lower half of the duodenum, and the rest of the small intestines, they are very numerous, and give to the surface of the mucous membrane an appearance like that produced by the pile of velvet. They are continued down to the ileo-cæcal aperture, and cease abruptly at its margin, covering the surface of the valve-segments next the ileum, but being wanting on the cæcal surface.

A good view of the shape, arrangement, and number of the villi may be obtained by examining a piece of villous mucous membrane fixed under water. In man, the villi are conical in shape, somewhat flattened, and measure in length from apex to base from the 1-60th to the 1-45th of an inch. They vary much in shape and size in the lower animals: in the dog, cat, and lion they are long and almost filiform; in the sheep and rabbit they are small, flattened, and conical; in the turkey they are large and lamelliform. Most fishes and reptiles are devoid of villi.

Fig. 159.



A. Villi of duodenum of dog, two hours after death, showing the substance of the villus retracted from the epithelial investment, like a finger from a glove. The process of digestion was not going on at the time of the dog's death, as there was no food in the stomach nor chyle in the lacteals. Magnified 80 diameters.

B. From the same part, and same dog, showing the epithelium corrugated, being attached and free at intervals. Magnified 80 diameters.

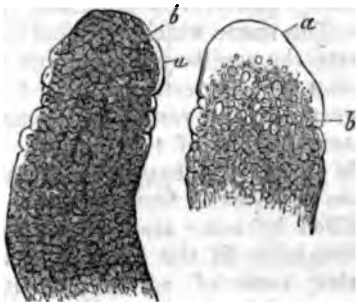
In structure, a villus resembles an everted Lieberkühn's follicle:—the same elements exist in both; basement-membrane, epithelium, subbasement tissue, which occupies, along with vessels and perhaps nerves, the interior of the villus. The difference between the two structures is, that the epithelium is in the interior of the follicle and on the exterior of the villus.

A single layer of the columnar epithelium co-

* Dub. Hosp. Rep. vol. v. p. 163.

ach villus (Fig 159). The particles adhere by their sharp ex-
ies to the basement-membrane, and their bases, packed to-
, present on the surface an appearance of a pavement.
basement-membrane is readily seen when the epithelial layer
ff, which it is apt
during the diges-
rocess (Fig. 160).
a single layer of
eneous membrane,
h which, or in the
of the villus, are
in well - injected
ens, the bloodves-
the villus.
h villus is provided
plexus of capilla-
A single artery en-
s base, and, pass-
p its centre, forth-
breaks up into a
ry plexus, which
n at all points of
rface of the villus,
iately beneath the
ent - membrane. —
this arise at vari-
oints small veins, which pass out of the villus in one or more
s (Fig. 162).
cavity of the villus also contains one or more small lacteals,
ich originates the proper lacteal plexus of the intestine. The
re seen white with chyle, during the absorption of that fluid,
e chyle may be fixed in them by coagulation, if the membrane

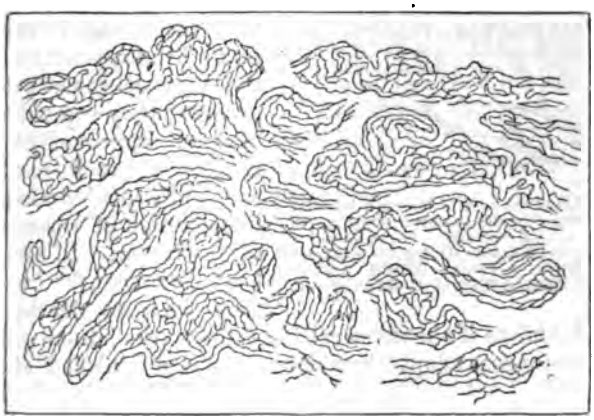
Fig. 160.



A. From the same part of another dog, fed 2½ hours before death, showing the columnar epithelium stripped off, and the cellular substance of the villus covered merely by basement-membrane. Magnified 200 diameters. *a*. Basement-membrane, slightly raised. *b*. Cellular substance of the villus, disposed somewhat in columns.

B. From the same part and same dog, showing villus denuded of epithelium, and the basement-membrane raised in a bulla by the endosmosis of water, in which it was immersed. Magnified 200 diameters. *a*. Basement-membrane. *b*. Cellular substance of the villus.

Fig. 161.



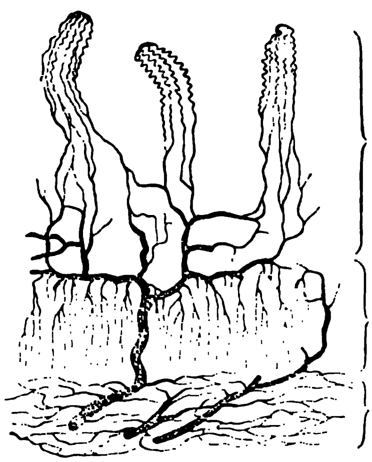
ry plexus of the villi of the human small intestine, as seen on the surface, after a successful , magnified 50 diam.

is promptly immersed in alcohol. Respecting the manner in which these vessels are disposed in the villus, however, nothing certain is known. Some have described a network of these vessels extending to the extremity of the villus. The investigation is one of the most difficult in minute anatomy, and is highly important as bearing upon the mechanism of the absorption of chyle.

Nothing whatever is known of the relation of the nerves to the villi. The tissue which occupies the cavity of the villus, and which supports the capillary plexus, and whatever other vessels may exist in it, is a soft, imperfectly formed areolar tissue, containing nuclei and granules, and resembling somewhat the tissue contained in the gustatory papillæ of the tongue. That portion of it which corresponds to the free extremity of the villus differs from the rest; it exhibits a vesicular structure, and resembles very minute fat vesicles, filled by some transparent fluid. The tissue which occupies the remainder of the villus seems to consist chiefly of nuclei or granules, some of which present an indistinct arrangement in columns, which are parallel to the axis of the villus. During the process of chylification it appears to be the seat of some very remarkable changes connected with the absorption of chyle.

The function of the villi appears evidently to be connected with absorption, and specially with the absorption of chyle. This view rests upon the following grounds: First, that the villi exist only in the small intestine, where the most active absorption of digested matters evidently goes on; and that they are most highly developed and most numerous in that part of the small intestine where chyle is first formed. Secondly, that during the process of chylification the villi are turgid with blood, and obviously present all the appearance of being the seat of some active vital process; they are enlarged and opaque, apparently from a change in the intravillous tissue, and probably also from the introduction of some new matter into them. In animals that have been kept fasting for some time prior to death, the villi look small, and as if shrunken within their epithelial sheaths, which, in some instances, adapt themselves to the diminished size of the inclosed villi, by becoming thrown into folds (Fig. 162). But during the digestive process the villi are large and full; the nuclei of their proper tissue are very distinct; the basement-membrane is

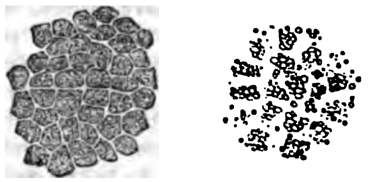
Fig. 162.



Vertical section of the coats of the small intestine of a dog, showing only the commencing portions of the portal vein and the capillaries. The injection has been thrown into the portal vein, but has not penetrated to the arteries. *a*. Vessels of the villi. *b*. Those of Lieberkühn's tubes. *c*. Those of the muscular coat.

here and there bulged by them on the surface, especially towards the free extremities, and the peculiar vesicular structure at the apices of the villi is compressed, or otherwise concealed from view or altered in character (Fig. 160). Lastly, the epithelium seems to adhere much less closely to the villi during chylification than during fasting; and the epithelial particles themselves appear to undergo some change during this process. This latter change is represented in the annexed cut (Fig. 163); the epithelial particles appear larger, their contents more distinct, and consisting of minute fatty grains as well as of some small globules.

Fig. 163.



A. B.

A. Epithelium detached, and free in the cavity of the duodenum, taken, immediately after death, from a dog fed $2\frac{1}{4}$ hours before. Each cell is filled with apparently fatty matter, partly granular and partly in globules. Magnified 600 diameters.

B. The same, suffered to stay an hour or two under the microscope, showing the fatty material aggregated into larger globules, the rest of the cell-structure having become indistinct.

Of the Glands of the Intestine.—These are, in addition to the Lieberkühn's tubes or follicles already described, and which are themselves secreting organs: 1. Brunner's, or the duodenal glands; 2. The solitary glands; 3. Peyer's glands, or *glandulæ aggregatæ.*

Brunner's glands belong properly to the duodenum. They were discovered and described by J. C. Brunn in 1686. We find them in the submucous areolar tissue, disposed as a more or less thick layer of whitish grains, immediately beneath the mucous membrane. They may be compared to the elementary grains of a salivary gland spread out on an expanded surface instead of being collected into a mass. Near the pylorus they are most numerous, and most closely set and largest; towards the termination of the duodenum they become much fewer, smaller, and scattered; and nothing resembling them is found in any other portion of the intestine. They are much more developed in the Herbivora than the Carnivora; in man, they are large and numerous, generally speaking, but exhibit a good deal of variety in different subjects, and, in the very old, they appear to have wasted and shrunk.

Fig. 164.

Vertical section of the mucous membrane of the duodenum in the horse, slightly magnified, showing v, villi, *b*, *c*, mucous membrane and submucous tissue. *g*. Brunner's glands cut vertically, and a little spread out, showing their lobulated structure.

In point of structure, Brunner's glands resemble precisely the pancreas. Their ultimate elements are bunches of vesicles which contain globular epithelium, and from which ducts arise which coalesce and form larger ducts, through which the secretion is

poured into the duodenum. The exact relation of these ducts to the tubes of Lieberkühn is not known.

Brunner's glands, no doubt, secrete a fluid similar, perhaps, in nature, to the pancreatic fluid, which exercises an influence on that portion of the digestive process which takes place in the duodenum. Their restriction to the upper portion of the intestine, and their mode of arrangement in an expanded form beneath the mucous membrane, establish for them an analogy with the buccal glands, which are similarly disposed beneath the mucous membrane of the mouth, and which bear to the salivary glands the same relation as the duodenal glands do to the pancreas.

Fig. 165.

A solitary gland from the small intestine of the human subject, magnified.—After Boehm.

These glands, restricted as they are to the upper portion of the intestine, give a character to it of a physiological kind, and therefore more definite than any external boundary. Accordingly, while the duodenum may properly give its name to these glands, so the presence and extent of them should denote that portion of intestine which may be called duodenum, and define its limits.

The *solitary glands* are found in all parts of the intestine, but are most numerous in the jejunum, in the cæcum, in the vermiform appendix, and in the rest of the large intestine. When filled with their secretion they are like small grains, about as large as those of mustard-seed, placed beneath the mucous membrane in the submucous tissue, which cannot in those situations be inflated; they may be readily seen by holding up the intestine against the light. When empty and collapsed, they are not easily discovered, and therefore are frequently overlooked.

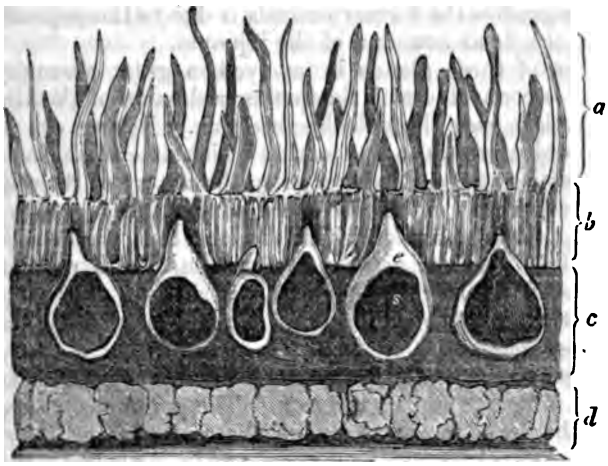
Fig. 166.

A patch of Peyer's glands of the adult human subject, from the lowest part of the ileum.—After Boehm.

One of these glands is a simple vesicle, or sacculus, of membrane, shaped like an India-rubber bottle, with a narrow extremity corresponding to the surface of the mucous membrane, and a rounded obtuse base, imbedded in the submucous tissue. Its precise relation to the elements of the mucous membrane cannot be exactly determined; its wall seems to be formed of a structure distinct from the basement layer of that membrane. It projects among Lieberkühn's tubes, and, in the

small intestine, is concealed and covered by the villi of the mucous membrane. Within it is contained a variable quantity of nuclei and granular particles, which, in the present state of our knowledge, must be viewed as a secretion. How this secretion is discharged is a matter of uncertainty, as no orifice has as yet been clearly demonstrated; hence some anatomists regard these glands as closed vesicles, which burst when distended to a certain point.

Fig. 167.



Vertical section through a patch of Peyer's glands in the dog. *a.* Villi. *b.* Tubes of Lieberkühn with the apices of Peyer's glands. *c.* Submucous tissue with the glands of Peyer imbedded in it. *d.* Muscular and peritoneal coats. *e.* Apex of one of Peyer's glands projecting among the tubes of Lieberkühn. The glands are seen laid open by the section. Magnified about 20 diameters.

*Peyer's Glands.**—These may be regarded as aggregations of solitary glands, forming circular or oval patches situated on the free border of the intestine (Fig. 167). They belong particularly to the ileum, and ought to be regarded as forming a special anatomico-physiological feature of that portion of the intestine, and as indicative of its proper limits. We find in man as many as from seventeen to twenty-two patches, but with great variety both as to number and size. The patches are smallest towards the jejunum, and increase considerably in size towards the cæcum, so that some quite near the latter intestine measure from two to four inches in their long diameter.

Each of the small glands, the aggregate of which constitutes the patch of Peyer, is placed in a depression and surrounded by a groove resembling that which surrounds the papillæ vallatæ of the tongue;

* The glands, so long known by this title, may be called "Grew's glands," with as much justice. They were discovered in several animals by our countryman, Dr. Nehemiah Grew, who also delineated them with great accuracy, and described them in his lectures to the Royal Society, in the year 1676, before Peyer's book was published (1677). Dr. Grew's descriptions and delineations may be found in an essay appended to his catalogue of the museum of the Royal Society, of which he was Curator, entitled "The Comparative Anatomy of the Stomach and Guts begun." See the advertisement prefixed to this work.

some being inclosed by a circle of the orifices of large tubes of Lieberkühn. It seems to be in every respect similar, as regards its intimate structure, to the solitary glands, and probably discharges its secretion by a similar mechanism. The arrangement and structure of these glands are well seen in a vertical section, as represented by Fig. 167.

Peyer's glands are well developed in the Carnivora, more so than in Herbivora, and they commence very high up in the intestine, whence it would appear that the shortness of the small intestine which distinguishes the former animals is due to the imperfect development of the duodenum and of the jejunum.

The office of these glands is involved in great obscurity; most probably it is connected with the further reduction of the alimentary matters as they pass through the intestine. But we are unable to form any conjecture as to the causes which determine the peculiar shape or position of the glands, or as to the nature of their secretion. They are larger and more developed during the digestive process than during fasting, a fact which denotes that the former is the period of their greatest activity of function. It is not impossible that the peculiar odour of the feces, which is in a great measure characteristic in particular classes of animals, may be due to a secretion by these glands.

In typhus or typhoid fever, these and the solitary glands are prone to become inflamed and to ulcerate. The poisonous matter which generates the fever is apt to fix on these glands; or they may be the special channel for its elimination, and in the process they suffer irritation. In phthisis, these same glands are very liable to become the seat of the tubercular deposit, and also of an ulcerative process, whence results the diarrhœa which proves so troublesome an accompaniment of that disease.*

In Asiatic cholera, all these glands become greatly enlarged from the accumulation of a large quantity of granular matter in the vesicles.

Brunner's glands exhibit a remarkable immunity from disease, and in this, as in other respects, they resemble the pancreas.

In concluding the account of the anatomy of the intestinal tube, the following summary of the special characters of each portion of it will serve to indicate more clearly what we have alluded to above—that the physiological anatomy of the mucous membrane affords the best basis for its subdivision into portions, each of which, no doubt, exercises its special function in the digestive process:—

In the *duodenum*, the mucous membrane exhibits: 1, cells and tubes like pyloric cells, gradually passing into straight Lieberkühn's tubes, which exist throughout the rest of the gut; 2, villi commencing in the upper part by the elongation of the septa between the cells,

* Some excellent remarks on the structure of the solitary and Peyer's glands may be found in a paper by Dr. Handfield Jones, "On the Intestinal Mucous Membrane."—*Lond. Med. Gazette*, 1848.

becoming extremely numerous and crowded together in the two-thirds; 3, in the lowest third a few solitary glands; 4, r's glands, very numerous in the upper part, gradually dimin- n size and number below; 5, valvulæ conniventes, well de- in the inferior half.

›rifice by which the biliary and pancreatic ducts open into stine, is placed where Brunner's glands have either become w or have ceased. In most of the Carnivora which we have ›d, these ducts open below the region of Brunner's glands; ıt at which they pour their contents into the bowels has there- constant relation to the duodenum, if, as it is convenient to may make the presence of these glands the characteristic ' that portion of the intestine.

ıe *jejunum*, the mucous membrane is characterized by, 1, ühn's follicles and villi well developed; 2, valvulæ conni- larger and more complete than elsewhere; 3, solitary

ileum exhibits: 1, Lieberkühn's follicles and villi well deve- own to the ileo-cæcal valve; 2, valvulæ conniventes, which ly diminish towards the termination of the ileum, and disap- 3, solitary glands; 4, aggregate glands, or Peyer's patches, re small at the upper part of the ileum, but greatly increase at its lowest portion.

mucous membrane of the *cæcum* and of the *whole large in-* is distinguished by the complete absence of villi; by the e of Lieberkühn's follicles and of solitary glands of large ıich are numerous in the vermiform appendix, as well as in um itself; and by the folds which form the partitions be- he cells of the colon, as well as by the valvular folds of the

ments of the Intestines.—The substances which enter the al canal from the stomach are moved onwards by means of called the peristaltic, or the vermicular action of its muscu- ;.

action of the intestines is very conspicuous in animals opened ately after death; under these circumstances it is probably xaggerated state, owing to the stimulus created by the en- of cold air into the abdomen. It may be displayed in a active state by subjecting the intestinal canal of an animal ›d to the influence of the magneto-electric machine, by the ive shocks of which this action becomes greatly increased in y and rapidity, though not altered in character.

›gs and cats, in which we have most frequently observed the ltic action, it seems to commence at the pyloric third of the ı, whence successive waves of contraction and relaxation (the being instantly succeeded by the latter) are propagated ıout the entire length of the small and large intestines. The e of the waves is always downwards. In examining a por- intestine at the moment of its contraction, we perceive a di-

latation above it as well as below it; the latter being produced by the protrusion into it of the contents of the now contracted portion of intestine; the former, by the relaxation of a previously contracted portion. The rapid succession of these contractions and relaxations give to the movements of the intestines the appearance of the writhings of a worm, whence they are distinguished by the appellation *vermicular*. Sometimes we have opportunities of observing these movements during life in man, in cases of extreme attenuation of the abdominal parietes; or in cases where, from some great obstruction in the course of the alimentary canal, the peristaltic action is very much increased in intensity above the seat of the obstruction; or in wounds of the abdomen; or during surgical operations.

There are certain facts which justify the supposition that this vermicular action has a proper rate of speed in each individual, and that substances introduced into the highest part of the intestinal canal take a certain time, varying in each particular case, to traverse it. For example, the act of defecation will, if allowed or encouraged, take place with the utmost regularity every twelve or twenty-four hours, and the quantity discharged will exhibit but little variation, the quantity and quality of the food remaining the same; and indigestible substances taken with the food, seeds, husks, skins, &c., will at certain intervals appear in the feces, having traversed the whole canal. There is no act of the animal economy more strikingly under the influence of habit, *i. e.*, under the control of physical causes, without mental interference, than this of defecation; nor, on the other hand, is there any act which may be more completely deranged by its being *baulked*, through the resistance which the will can oppose to it. The intestinal movements are partly due to the influence of the stimulus of distension upon the muscular tunic, and partly to the reflex action of the ganglia of the intestinal portion of the sympathetic, stimulated by the contact of the intestinal contents with the mucous membrane. Direct irritation of the solar plexus, or of the semilunar ganglia, produces a marked increase in the movements of the intestines (*Vide* p. 508).

When obstruction exists at a certain point of the bowels they become dilated above that point, and when the dilatation has attained a certain amount their contents are found to flow back into the stomach, and are ejected by vomiting. This is commonly supposed to be due to an inverted direction of the action of the muscular tunic of the intestines (antiperistaltic action). But Dr. Brinton has very ably shown that there is no antiperistalsis of the bowels under these circumstances, any more than of the stomach in vomiting, and that the altered course of the fluids is due simply to their reflux along the axis of the intestine from the seat of obstruction. The muscular coat of the bowels acting in the downward direction, and with force proportionate to the obstacle, propels the fluids to a point where they encounter insuperable resistance, and whence they must take the course which affords least or no obstacle. Thus, a backward current is established in that part of the fluid least influenced

walls of the intestine, that, namely, which occupies its axis, r. Brinton's words, "*an axial reversed current* is developed, eturns matters from the neighbourhood of the strangulation to gher point in the canal." When fluid returns along the sides inge with a piston not water-tight, we have a somewhat ana- henomenon, and we may imitate the reversed movement of stinal fluids by trying to push water through an obstructed the piston of which is perforated in the cen- llustrated by the annexed wood-cut (Fig. 168).* ontents of the intestine are moved on, portion ion, much as in œsophageal deglutition. And, progress, they are mingled with fluids poured a the intestinal mucous membrane.

Fig. 168.

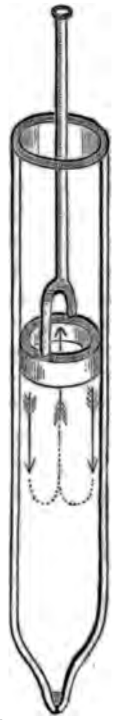


Diagram to illustrate the formation of a backward axial current in pushing water through an obstructed syringe with a piston perforated in the centre.

ges in the Mucous Membrane during Intestinal m.—During intestinal digestion, the mucous ne exhibits an increased nutrient activity, as by a greater afflux of blood, and by free secre- well as absorption; in connection with which ction it exhibits peculiar changes, which must ally noticed. It is red, moist, and covered with or less abundant mucus, &c.

most remarkable change which takes place in ous membrane of the intestinal canal is ob- n that portion of it which is covered by villi; throughout the small intestine, especially below it of entrance of the hepatic and pancreatic The villi are the agents of a peculiar process ption; and the changes which take place in them period appear to have immediate reference to which they perform in this function. They enlarged and turgid, partly owing to an in- afflux of blood to them, and partly in conse- of a change which takes place in the intra- tissue, whereby the component nuclei and acquire an increase of size, and some of them themselves in lines passing from the free ex- to the base of each villus (Fig. 160, A). These pear to proceed from an accumulation of small med at the free extremity of the villus within y (Fig. 160, B *b*): they are quite opaque, and ructure is, therefore, impenetrable to high in the microscope; they coalesce at the base of each villus, which we have not succeeded in tracing them.† is period an abundant quantity of loose epithelium is in with the mucous membrane, and surrounds the villi; and the

ributions to the Physiology of the Intestinal Canal, *loc. cit.*, a highly ingeni- teresting paper.

henomena here described were observed in dogs and cats fed in the ordi- upon meat, milk, &c.

sheaths of the latter seem to adhere very loosely to them, and may be much more readily detached than when the digestive process is not going on.

Mingled with the abundant mucus of the intestine, we find at this period very numerous white flocculi of a soft, loose, curdy material, the whiteness of which is conspicuous in the midst of other matters, which are more or less coloured from intermixture with bile. And, at the same time, the plexus of lacteal vessels, which is formed beneath the mucous membrane, and from which the larger lacteal vessels proceed through the mesentery to the mesenteric glands, is filled with a white fluid of the exact colour and appearance of milk, commonly called *the chyle.*

The display of the lacteal vessels filled with white chyle, at this period, is one of the most interesting sights among the many wonderful objects which engage the observation and the attention of the anatomist.

The white flocculent matter is most abundant in the duodenum and jejunum, and there the villi are most numerous; thence, likewise, proceed the greatest number of lacteal vessels. Lower down in the small intestine the flocculi gradually become less and less numerous, and ultimately disappear, the contents of the intestine consisting of a more or less fluid mass, apparently homogeneous, and coloured by bile. At the same time the villi become fewer and smaller, the number of lacteal vessels diminishes, and the glandular apparatus of the intestinal mucous membrane is more developed and distinct.

The occurrence of the flocculent matter, in that part of the intestine where the absorbing organs and the chyliferous vessels are most numerous, denotes that it must be regarded as constituting the nascent condition of that fluid which at this period fills the lacteal vessels and gives them their white colour—the chyle. It appears like a precipitate from the general mass of the intestinal contents, and many distinguished physiologists have regarded it in that light, and have attributed its precipitation to the addition of the biliary and pancreatic fluids to the chymous mass which has been pushed on from the stomach into the intestines.

This flocculent matter consists of a multitude of minute molecules apparently of a fatty nature (as they disappear under the action of ether), mingled with larger oil-globules, and also of numbers of particles of columnar epithelium, containing within them several fatty molecules of large size, readily distinguished by their highly refractive power. The contrast between the epithelial particles obtained from this flocculent matter, and those of the intestine of an animal that had fasted for some time before death, is very striking, and indicates that they undergo a change during chylification, either connected with the absorbing process or with the transformation of the alimentary substances. (Fig. 163.)

Of the peculiar mechanism by which this nascent chyle is introduced into the lacteal vessels, and of the nature of the changes which it undergoes in them to form perfect chyle, we can form no adequate idea in the present state of our knowledge. We do know, however,

that the material before its entrance into the vessels is very different from what it becomes after its introduction; and that in its advance towards the centre of the absorbent system it undergoes further changes, all of which tend to assimilate it more nearly to the blood itself.

Of the Chyle.—If, as seems most correct, we apply the term chyle to the fluid contained in the lacteal vessels during and shortly after digestion, we must make the distinction between *white* chyle and *transparent* chyle. The white chyle is a milk-like fluid, homogeneous in appearance, which, on being withdrawn from the lacteals and allowed to stand, separates, as blood would do, into serum and a clot. This clot consists of fibrine, which entangles, by its coagulation, certain particles proper to the chyle. These are chyle-corpuscles or globules, in every respect similar to lymph-corpuscles, and an infinite multitude of particles of extreme minuteness, to which Mr. Gulliver has given the name of *molecular base* of the chyle. These particles consist of fatty matter in a state of extreme subdivision.

During fasting, and also during the digestion of food wholly devoid of fat, the fluid contained in the lacteals is perfectly transparent and colourless, and not to be distinguished from the lymph of the lymphatics. In this fluid there is no molecular base, while all the other elements of the chyle are present. Hence there can be no doubt that the white colour of the chyle is due to the presence of the molecular base.

The chyle may exhibit various degrees of milkiness, according to the quantity of the molecular base. The white chyle, therefore, is chyle with molecular base in greater or less quantity; the transparent chyle is devoid of molecular base. Both kinds of chyle consist of a *liquor chyli*, essentially the same as the *liquor sanguinis*, holding suspended in it chyle-globules in the transparent chyle, and in the white chyle-globules, fat-globules, and molecular base.*

It would seem to follow, from observing the changes which the food undergoes in the small intestine, that the immediate office of that portion of the intestinal canal is to form this chyle; and it appears probable that the secretions poured into the small intestine from the glands, especially the liver, pancreas, and the glands of Brunner, which communicate with it, exercise a chemical influence upon the alimentary matters whereby this material is formed. We shall see further on that this view receives strong support from the results of experiments and observations respecting the functions of the pancreas and liver.

Changes of the Food in the Small Intestine.—It remains now to inquire whether all the digestible food which passes from the stomach undergoes the change into chyle, or whether certain parts of it only are simply dissolved and pass by absorption directly into the portal blood, as in the stomach, whilst other parts are converted into chyle, and enter a different part of the circulation through the lacteal vessels. In other words, is it necessary that all food, prior to its

* See the Chapter on ABSORPTION.

appropriation by the blood as nutriment, should pass through the condition of chyle?

As it has been shown that the stomach can absorb certain fluids and dissolved solids, through the absorbing power of its bloodvessels, there can be no good reason for denying the same power to the intestines, which have a vascular system precisely of the same kind as that of the stomach. Now the substances which the stomach completely dissolves and absorbs, are the azotized aliments: it seems not unreasonable to conclude that such portions of these aliments as have escaped absorption by the stomach, may undergo a similar solution in the intestines, and be absorbed by their bloodvessels without passing through the state of chyle.

But to answer this question accurately we must determine precisely the changes which each kind of food undergoes in the intestine.

Bouchardat and Sandras have obtained from their experiments results which indicate that fibrine does not undergo the change into white chyle. They fed animals with fibrine, coloured with saffron or cochineal, and were unable to detect any trace of the colouring matter in the chyle. They found, likewise, that the contents of the lacteal vessels of animals kept fasting differed in no respect from that of animals fed on fibrine. These experiments, therefore, render it highly improbable that fibrine contributes to the formation of white chyle, and Tiedemann and Gmelin had long since found that the quantity of fibrine contained in the lymph and chyle, after a long fast, is not less than that which is found there after digestion. Bouchardat and Sandras obtained the same results in their experiments on animals fed on albumen, caseine, or gluten, as on animals fed with fibrine; these substances, therefore, must likewise be excluded from the list of those which are capable of forming chyle. Hence the whole class of neutral azotized substances, admitting of solution by pepsin, may be absorbed without passing into the state of chyle.

Neither does it appear to be necessary for the appropriation of amylaceous aliments that they should pass into the condition of chyle. These substances are but little digested in the stomach. and undergo their principal changes in the small intestines. Here the pancreatic fluid exercises a similar influence upon them to that which the neutral azotized matters experience from the gastric juice. Bouchardat and Sandras found that a few drops of pancreatic fluid, added to some boiled starch, and kept at the temperature of from 95° to 104°, dissolved it in a short time, the liquid became transparent, and all trace of starch disappeared. The same effect is produced if a piece of the pancreas be used instead of the pancreatic fluid.*

* Dextrine is a substance having some of the properties of gum, and obtained from starch by the action of heat, diastase, or dilute acids. It is soluble in water, and exists in almost every part of plants. When starch is boiled in water for some time, an abundance of dextrine is produced. If the action of diastase or of the acids be continued too long, or if the quantity of either be too large, grape-sugar is produced. Hence dextrine may be regarded as the first stage in the transformation of starch into sugar. The formula for dextrine is C^{12}, H^{10}, O^{10}.—See *Mulder's Chemistry of Animal and Vegetable Physiology*, by Johnston, p, 224.

The starch in these experiments is converted into dextrine, or into sugar, in which state it is soluble, and thus admits of direct absorption into the bloodvessels, or the sugar undergoes a further change into lactic acid, and in this condition passes into the circulation. It appears that the presence of a free alkali is as necessary for these changes, as that of acid is needed for the solution of the neutral azotized substances. If the pancreatic fluid be acidulated, it ceases to act on starch, but, according to Bernard and Barreswil, acquires the power of dissolving albumen, fibrine, &c. We do not, however, find that alkalized pepsin is capable of dissolving amylaceous matters.

Bouchardat and Sandras have examined the changes which starchy substances undergo in the stomach and intestines in dogs. Man and carnivora are unable to digest raw starch in the stomach or intestines. Raw potato-starch introduced in a muslin bag into the stomach through a fistulous opening in the walls of the stomach, and withdrawn after a sojourn of twenty-four hours in that viscus, showed no sign of any change; nor did the gastric juice out of the body, the mixture having been kept at a high temperature for the same time, exert any influence upon the starch grains. When dogs were made to swallow raw starch, the grains were afterwards found intact in every part of the intestinal canal. Rabbits and granivorous birds, however, were found to possess the power of digesting raw starch, although more slowly than that which had been cooked. But this power was found to reside mainly in the upper part of the small intestine, and as the grains of starch became gradually fewer as the food descended in the intestinal canal, it seems reasonable to believe that each succeeding portion exercises a certain digestive power over them. In birds, the digestive power of the small intestine was greater than in rabbits, the lower part of the intestine in the former exhibiting no traces of the starch grains. In the upper part of the small intestine sugar and dextrine were found, and the lower the contents had passed down, the more did all traces of starch disappear.

Boiled starch is more readily digested by all animals than raw; to the carnivora and to man, cooking is essential to its perfect digestion. The same changes take place in it as in the raw starch, *i. e.*, it seems to undergo conversion into sugar, dextrine, and lactic acid. This change, however, is very slow and gradual, and although it occurs chiefly in the upper portion of the intestine, it is found taking place throughout the whole canal. The rapid formation of sugar in the intestinal canal leads to a proportionally rapid absorption of it, and to the elimination of it by the kidneys. It is apparently to guard against this, to protect the kidneys against the irritating influence of this substance, that the change of the starch into sugar and dextrine goes on with great slowness throughout the whole intestinal canal.

Our own experiments have yielded results similar to those of Bouchardat and Sandras, and confirm their conclusion, that neither azotized matters nor amylaceous substances contribute to form the

true white chyle. At least it may be affirmed that when animals are fed on such food, carefully freed from all oily or fatty matters, the fluid which is found in the lacteal vessels is perfectly transparent, and in all respects identical with that which is found in them after a long fast. We select the following experiments in illustration of this statement:—

Exp. 1.—A cat was fed on horse-flesh, carefully freed from fat, on the 7th of July, 1848. On the two subsequent days it was fed on the whites of eggs, freed from yelk: and on the 10th, it was fed on the whites of five eggs, at nine o'clock A. M. At half-past one P. M., on the same day, it was killed. The thoracic duct was filled by a perfectly limpid chyle, which exhibited no molecular base, a few chyle-corpuscles, and a few blood-corpuscles. The lacteals were with difficulty visible in consequence of the transparency of the fluid by which they were filled. The stomach and duodenum contained pieces of softened albumen, as well as a considerable quantity of a soft homogeneous jelly-like mass. In the latter intestine the villi were covered with epithelium, and did not exhibit any appearance to indicate that they were the seat of an active process of absorption.

Exp. 2.—A small healthy terrier was fed at nine A. M. with half a pound of wheaten bread, having previously fasted twenty-four hours; it was killed at one o'clock on the same day. The thoracic duct was filled with a clear fluid, which, when collected on a slip of glass, exhibited a faintly reddish hue. Under the microscope it was found to exhibit numerous red blood-corpuscles, with a much small number of white corpuscles, but more than the usual proportion for blood. No *molecules* were perceptible. The fluid, when collected in a watch-glass, coagulated in two minutes into a firm clot. A small quantity of softened bread was found in the stomach, and a still smaller quantity of the same bread very much softened, liquid, diffused, and coloured by bile, was found in the duodenum. In both, the contents were acid. The villi were covered with epithelium, which adhered firmly to them, without any great opacity of their interior, or other indication of activity of function. On chemical examination, by our friend Mr. Lionel Beale, junior, a highly competent analyst, the contents of the stomach were found to consist of a small quantity of sugar, with a good deal of starch; while in the duodenum, sugar existed in great abundance, and the starch only in very minute quantity.

Exp. 3.—A similar dog to the preceding was fed at the same time with two ounces and a half of horse-flesh, and the same quantity of beef suet; it was killed four hours and a half after having been fed. The whole lacteal system was distended with a white milky chyle, which, under the microscope, showed a large quantity of *molecular* matter, as well as red and white blood-corpuscles. The contents of the intestine were more or less acid throughout, and abundantly coloured by bile. There were very numerous white flocculi, most conspicuous in the duodenum, and becoming gradually less numerous to within an inch or two of the cæcum, where they

These flocculi consisted of an abundance of granular matter
›lumnar epithelium, having the free ends of the particles
ith minute oil-globules, while the neighbouring epithelium
ed no oily matter. The villi were mostly stripped of their
al sheaths, or held them very loosely; the intra-villous
re was opaque, and the vesicular structure beneath the base-
embrane at their free extremities was very distinct.
as evident in these experiments that the marked contrast
ı the state of the contents of the lacteals, and the condition
illi, was connected with the presence or absence of fat in the
ıd that so long as the food was purely albuminous or fibrin-
mainly amylaceous, the chyle was transparent, and the villi
ıtly inactive; but that the addition of fat to the food called
i into activity, and filled the lacteals with an abundant milky

we to infer then that the lacteals absorb fatty matters only,
.t the villi are altogether inactive, save when fatty or oily
ces are to be absorbed? We apprehend that such an infer-
not justifiable; it may, however, be concluded that the villi
lacteals are capable of absorbing all substances which the
ssels absorb, and by a simple process; but that the absorp-
fatty matters devolves upon them only, and is a more com-
ocess, involving considerable changes in their tissue.
upon similar grounds we may conclude that while albuminous
:inous aliments contribute to the formation of chyle, they do
:essarily undergo the change into chyle in order to be ab-
But fatty matters appear to admit of absorption in no other
:cept by a reduction to the state of molecular base of the
hyle.
e observations and experiments denote sufficiently clearly
o channels exist for the transmission of the nutritious mat-
›m the intestines to the blood; one through the lacteals, by
i; the other directly through the walls of the bloodvessels
.ves. Matters taking the latter route must pass through the
nd would be subjected to the influence of that gland before
ach the *inferior* vena cava and the right auricle, while those
through the former channel must permeate a totally distinct
of vessels, namely, the lacteal system, to be conveyed to the
r vena cava and to the right auricle, where, having mingled
e blood coming from the liver, both are transmitted by the
entricle to the lungs.
it would seem that the object of the two modes of absorption
intestine, and of the two paths of transmission from the in-
to the centre of the circulation, is to keep separate, up to a
point, two kinds of material resulting from the digestion of
l. And probably the reason why one kind of product is re-
to pass through the intricate capillary plexuses of the vascu-
tem of the liver, to the exclusion of the other, is because it
s material out of which the liver may elaborate bile; whilst

the other material is transmitted through a less complicated series of channels more directly to the lungs.

Of the Offices of the Pancreas and Liver in Digestion.—The presence of two such great glands as the pancreas and the liver existing in a large portion of the animal kingdom at the upper part of the intestinal canal, and pouring their secreted fluid into it, obviously denotes a connection between the fluids secreted by these glands, and the changes which the food undergoes in this part of the intestine.

As the function of the pancreas has been determined with greater accuracy than that of the liver, it will be more convenient to consider it first.

Function of the Pancreas in Digestion.—The presence of the pancreas is constant, at least, in the vertebrate classes.

It is present in all the mammalia—it is, perhaps, better developed in carnivora than herbivora; in all it is in intimate relation with the upper part of the small intestine into which it pours its secretion by one or two ducts. In some, as in man, the pancreatic duct and the common choledoch duct open into the duodenum at the same place; in others they open at some distance from each other (as much as sixteen or seventeen inches in the rabbit) but in all they open into the same portion of the intestinal canal; and the pancreatic duct, always *below* the biliary duct, when they do not open together. Some doubt exists as regards its presence in fishes. In rays and sharks, a solid gland exists, corresponding to the pancreas; and in osseous fishes a similar gland has recently been discovered by Stannius, which appears to be its analogue.*

The secretion of the pancreas has some resemblance to saliva. It has been lately studied with great care by M. Bernard, from whose clear and admirable memoir the following account of it is derived.

The pancreatic fluid may be procured most readily and in greatest quantity at the commencement of the digestive process. Bernard obtained it from the dog in the following manner: the animal having been well fed, after a fast of some hours, an incision was made into the abdomen below the margin of the ribs sufficiently large to enable the operator to draw out the duodenum, and with it a portion of the pancreas. The larger of the two pancreatic ducts was now rapidly isolated, and opened with fine scissors, and into this opening a silver tube was introduced and fixed in the duct by a ligature. The intestine and pancreas were replaced, and the wound in the abdomen closed by suture, the free extremity of the tube being allowed to project through it. To the silver tube was now attached a small caoutchouc bag, perfectly exhausted of air, and to the opposite end of this another similar tube was fixed. The pancreatic fluid flowed freely through the first tube into the caoutchouc bag, and accumulated there; and as much as two drachms and a quarter were col-

* Müller's Archiv., 1849.

ected in five hours and a half. The fluid flowed from the tube freely drop by drop.

When this operation was performed at the commencement of digestion, Bernard obtained, between half-past seven A. M. and five P. M., four drachms and one third of the fluid, making an average of nearly half a drachm an hour.

On the following day, when signs of inflammation had shown themselves in the wound, more than four drachms of the fluid were obtained in one hour and a quarter. The *quantity* of the secretion was considerably increased, but its *quality* was altered—its consistence being much diminished, and its physiological properties materially changed.

When the experiment was performed on an animal in which the digestive process was fully established, the quantity of fluid obtained was much less than at the earlier period, but its quality much the same. During abstinence, only a very small quantity of the pancreatic juice could be obtained at the time of the operation; but the following day, when the wound became inflamed, a fluid much altered in quality flowed out very freely.

If the operation were slowly performed, so as to expose the intestine long to the action of the air, and to irritate it and the gland, the quantity and quality of the secretion were much altered.

As the characters of the pancreatic fluid vary so readily with the circumstances attending the operation of obtaining it, Bernard describes two kinds of fluid, the first being the *normal*, or that obtained under the best conditions, the second, the *morbid*, or that obtained after inflammation has commenced in the wound and in the pancreas.

The normal pancreatic fluid is a colourless, limpid fluid, viscid and gluey, flowing slowly by large pearly or syrupy drops, and becoming frothy on agitation. It has no characteristic odour—it has a slightly saltish taste resembling that of the serum of the blood. Bernard has always found it *alkaline* in reaction—never either acid or neutral. It coagulates by heat as completely as white of egg, becoming completely solid, and not leaving a drop of fluid. The mineral acids, likewise, cause it to coagulate, as also the metallic salts, alcohol, and pyroxylic spirit. It is not coagulated by dilute acetic, lactic, or hydrochloric acids. Alkalies cause no precipitate in it, but redissolve that thrown down by heat, acids, or alcohol.

This constituent of the pancreatic fluid, which is coagulable by heat, &c., although apparently identical with albumen, is not so: it differs from albumen in the following point. When the coagulum obtained from the pancreatic fluid by alcohol is dried, it can be redissolved completely and readily in water, and it gives to the water the peculiar viscidity of the pancreatic juice, and likewise its physiological properties, whilst albumen treated in the same way, undergoes scarcely any appreciable solution in water.

At a high temperature the pancreatic juice rapidly changes, is decomposed, and loses its property of coagulating by heat. At a low temperature it may be preserved for many days—when its vis-

cidity increases and it becomes of the consistence of a weak jelly. Bernard has examined the pancreatic juice in rabbits, horses, and birds, and has found it in all to exhibit the same essential character as in dogs.

We have already stated that the pancreatic fluid, or a piece of the pancreas itself, is capable of promoting the transformation of starch into sugar, and therefore of promoting the digestion of amylaceous matters. But that this power does not belong exclusively to the pancreatic fluid is evident from the fact that other fluids or animal substances are capable of producing similar transformations. Bernard has shown by direct experiment that the pancreatic fluid possesses the peculiar property, which is not enjoyed by any other animal fluid, of modifying in a special manner or digesting all the neutral fatty matters which are met with in food.

Thus by mixing fresh pancreatic juice, possessing the normal characters above described of viscidity and alkalinity, with olive oil, and shaking the fluids well together, a perfect emulsion is formed, and a liquid similar to milk or chyle is the result. A similar effect is produced by the admixture of pancreatic juice and fresh butter, or of mutton suet, or hog's lard, care being taken to expose the mixture in a sand-bath to a temperature of from 95° to 100° Fahr., so as to melt the butter and suet, and afterwards to shake the mixture well.

So perfect is the emulsion formed by means of the action of the normal pancreatic fluid upon fatty matters, that the mixture, if left from fifteen to eighteen hours at a temperature of from 95° to 100°, continues to exhibit the same colour and appearance, nor does any separation take place between the fatty matter and the pancreatic fluid. It appears, nevertheless, that the fat is not simply divided, and made into an emulsion, but that it has undergone a chemical change into glycerine, and a fatty acid; the fluid, which immediately after the admixture was distinctly alkaline, becomes, after remaining five or six hours, as distinctly acid. In the tube in which butter had been submitted to the action of the pancreatic juice, butyric acid was easily recognized at a distance by its characteristic odour.

We find that on rubbing up a piece of quite recent pancreas taken from an animal killed during the digestive process, with fat or lard, and a little water at a temperature of 95° or 100°, a very perfect white emulsion is quickly formed.

Bernard instituted experiments to ascertain whether other animal fluids possessed this power over oily or fatty matter. The fluids tried were bile, saliva, gastric juice, serum of blood, and cerebro-spinal fluid, but none of them were found to cause any permanent change, either mechanical or chemical, in the substances submitted to their influence.

It also appears, from Bernard's experiments, and this is a point which may throw some light on certain forms of dyspepsia, that in order that the pancreatic fluid should exercise its perfect action, it must be strictly normal. Bernard found that what he calls the *abnormal* fluid, namely, that which exhibits no viscidity, which is

atery and does not coagulate by heat, has no effect upon fatty sub-
ances.

To complete the proof of the special action of the pancreatic
id in the digestion of fatty matters, Bernard states that he has tied
the dog the two pancreatic ducts, of which the smaller opens quite
se to the choledoch duct, and the larger about three quarters of
inch lower down. Under such circumstances fat passes through
e small intestine unaltered, and the lacteals are filled with limpid
yle totally devoid of the white colour.

The influence of the pancreatic fluid in the formation of the white
yle, by its action upon fatty food, is beautifully illustrated by
rnard, in a very simple experiment upon the rabbit, which we have
peated with results precisely corresponding with those obtained by
m. The rabbit is selected for this observation, because, while the
oledoch duct opens into the duodenum just below the pylorus,
e pancreatic duct opens as much as sixteen or seventeen inches
wer down, so that all that length of intestine receives bile only.
small quantity of melted hog's lard was injected into the stomach
he animal having been kept without food for twenty-four hours
reviously), after which it was left to eat freely of parsley and carrots.
fter five or six hours it was killed. Between the openings of the
o ducts the lacteals contained a clear limpid fluid; but *below* the
ncreatic duct the lacteals were turgid with a rich white creamy
yle.

In confirmation of these results of experiments, it may be stated
at patients labouring under disease of the pancreas invariably suf-
r from extreme emaciation, and many cases are recorded in which
t appeared unaltered in the stools—apparently in consequence of
alignant disease of the pancreas. Cases of this kind are recorded
r Elliotson, Bright, and others.

From the preceding facts, so well collected by the industry and
uteness of Bernard, it seems to us that we must conclude that the
incipal function of the pancreatic fluid is to digest fatty matters,
at is, to reduce them to a state which will admit of their ready
sorption by the lacteals. This power is mainly due to the organic
inciple resembling albumen which is held in solution in the pan-
eatic fluid.

An objection to this view arises from the fact that some animals
ve no fat, or oily matter, in their food, as, for example, many vege-
ble feeders. This objection, however, may be thus met, that
arly all vegetable substances contain a certain proportion of oily
atter, however small—and, moreover, the pancreatic fluid might
rve to digest the fatty matters of the bile which, by absorption into
e lacteals, are readily carried to the lungs for combustion.

But that the digestion of fat food is not the *only* office of the pan-
eas in digestion, is sufficiently proved by the experiments of Bou-
ardat and Sandras, already referred to, which point out the import-
t share it takes in the digestion of amylaceous matters.

We may therefore conclude that the pancreas secretes a fluid of
hich the office is—first, and specially, to digest fatty and oily ele-

ments; and, secondly, to convert starch into sugar, and thus to promote the digestion and absorption of amylaceous food.

The Function of the Liver.—The liver is the largest gland in the body. It is remarkable not only for its complex structure, which will be described in the chapter on Secretion, but also for its peculiar double circulation. It is supplied with blood from two sources, namely, from the *hepatic artery*, which carries red blood to it, and is distributed mainly to the coats of the ducts—and from the *vena portæ*, a vein in structure, but an artery in its mode of branching, which conveys a large quantity of dark blood, derived from the veins of the stomach, the intestines, the pancreas, and the spleen, and which ramifies throughout every part of the liver, passing into a dense capillary plexus, whence it is taken up by the hepatic veins, and carried to the right side of the heart. By this arrangement all matters absorbed into the blood from the gastro-intestinal surface must pass through the liver, a point of anatomy which indicates that the material added to the blood by absorption from the stomach and intestines, in some way contributes to support the function of this gland.

We may justly assume that the bile is secreted from the blood of the vena portæ, because of the great size of that vessel and the vast extent of the capillary plexus, which it supplies, more especially as the small size of the hepatic artery compared with the great bulk of the gland, and the trifling degree to which it can contribute to the formation of the capillary plexus of the organ, clearly disqualify it for contributing to the secreting process.

The bile, as a separated product, first shows itself in the minute canals or ducts which originate in the substance of the liver, and which, by frequent successive junctions, form two large ducts, each somewhat larger than a crow-quill, which emerge at the transverse fissure of the liver, the one from its right, the other from its left lobe. These two ducts pass for a short distance downwards and inwards, enveloped by Glisson's capsule, along with the trunks of the hepatic artery and portal vein, and with the hepatic plexus of nerves and several large lymphatics, with some lymphatic glands. About an inch below their emergence they unite at an acute angle, and form a single duct a little larger than either; this is the *hepatic duct*, which soon unites with a short duct proceeding from the gall-bladder, the *cystic* duct. The union of these two ducts forms the *ductus communis choledochus*, between two and three inches in length, which passes behind the two upper thirds of the duodenum, and opens, along with the pancreatic duct, into that intestine, in or close to the angle of junction of its middle and inferior third.

The gall-bladder is a pyriform bag, placed in a depression on the inferior surface of the right lobe of the liver, and serving as a reservoir for the accumulation of the bile when its flow into the intestine is interrupted or retarded. We infer, at least, that this is its principal use, because it is always found full after a long fast, and empty when digestion is going on. Blondlot tied the common bile-duct of

dog, and established a fistulous communication between the gall-bladder and the external integument; thus the bile, which ought to descend into the intestine, would flow out at this opening. He states that while the animal was fasting sometimes not a drop of bile would escape at the orifice, even for some hours; but in about ten minutes after the introduction of food into the stomach, the bile would begin to flow freely, and continue to do so as long as digestion was going on.* The process of digestion in the duodenum appears to favour the flow of the bile into the intestine, either by the stimulus of the food in contact with the mucous membrane, acting by reflection upon the muscular coat of the gall-bladder, and causing it to contract and expel its contents, or, by altering its position, so as to favour the descent of the bile, or by changing the condition of the orifice of the duct, which in the empty state of the bowel would be closed by the contraction of the intestinal circular fibres. Indeed, it is probable that all these causes would be brought into operation by the duodenum becoming filled with food, and the digestive process being set up in it.

That the gall-bladder is not an essential part of the excretory apparatus of the liver is shown by the fact that it is not universally present even in the highest classes of animals. This reservoir is found in the animal series first in fishes; but it is absent from many genera of that class. It exists pretty constantly in reptiles and birds, being occasionally wanting in the latter, and in mammalia it is absent from many of the genera. We do not know the precise law which regulates its presence or absence, but it seems that the length of time for which animals are accustomed to fast has probably a good deal of influence. Thus, in the herbivora, which eat often, and at short intervals, and whose digestion is slow, the gall-bladder is frequently absent; and in the carnivora, which eat at long intervals, it is almost constantly present. But there are many of the herbivora in which it is present, as in the ox, the sheep, the goat, &c. In the first giraffe examined in this country by Professor Owen there was no gall-bladder; in the second two were found.†

Quantity of Bile secreted.—Various attempts have been made to estimate the quantity of bile secreted by the liver in a given time; but, in truth, we have no satisfactory knowledge on this point. Blondlot, by the experiment upon a dog detailed above, was able to collect the bile that flowed out at the external orifice, which must have been all that was secreted. The quantity thus obtained from one of his dogs amounted in twenty-four hours, on the average, to twelve drachms and a half. Assuming, then, with Haller, that the liver of a man secretes four or five times as much bile as that of a dog, we may conclude that the average quantity poured into the human intestine in twenty-four hours, is from six to eight ounces. Haller, himself, however, had formed a much larger estimate than this, namely, seventeen to twenty-four ounces.

* Essai sur les fonctions du Foie, p. 62.
† Art. "Liver," Cyclop. Anat. and Phys.

The Physical and Chemical Properties of Bile.—The bile is a thick, ropy fluid, of a greenish-yellow colour, a bitter taste, and a peculiar nauseous smell, with a specific gravity of 1026 to 1030. It has an antiseptic power, and not only itself resists putrefaction for a considerable period, but prevents substances with which it mixes from putrefying. The excessive fetor of the feces in some cases of jaundice from complete obstruction, and, perhaps, also in cholera, is probably due to the absence of the antiseptic influence of the bile. The reaction of the bile, according to Gorup-Besanez, when first secreted, neutral; but subsequently it becomes slightly acid, and ultimately alkaline. The well-known cleansing properties of ox-gall are due to the presence of alkali in it, in considerable quantity.

According to the analysis of Berzelius, which seems to be the most trustworthy, and with which that recently made by Mulder* accords very closely, bile consists of water holding mucus in suspension, and in solution certain salts, with a peculiar complex substance called by Berzelius *Bilin;* also fat, and a special colouring matter. The following is Berzelius's table of the analysis of ox-gall.

Water	904.4
Bilin (with fat and colouring matter)	80.0
Mucus	03.0
Salts	12.6
	1000.0

According to Berzelius's view of the composition of bile, its essential and most important constituent is the *Bilin*, a substance which has a remarkable tendency, under certain circumstances, to be metamorphosed into taurine, hydrochlorate of ammonia, and into two resinous acids, which he has named *fellinic* acid and *cholinic* acid.

Bilin is inodorous, and has a peculiar sweetish-bitter taste, most perceptible at the base of the tongue and fauces. This sweetness is attributed by Berzelius to the admixture of some glycerine, which may be derived from the fatty matters of the bile. It dissolves readily in water and in alcohol, but not in ether. It is neutral, and forms soluble combinations with acids and bases.

The substances above named may be obtained from bilin by digesting it in dilute hydrochloric acid. The fellinic and cholinic acids are insoluble, the others are soluble in water.

Taurine is a crystalline substance, consisting of colourless six-sided prisms. It dissolves in about sixteen times its weight of water at 60°, and is more soluble at a higher temperature. It contains sulphur, according to Redtenbacher.† Its composition is represented by the formula $C_4N_2H_4O_6S_2$. The *fellinic* and *cholinic* acids resemble each other very much in their external properties. They are little or not at all soluble in water, but are readily dissolved by alcohol; the *fellinic* acid is readily dissolved by ether, the *cholinic*

* Untersuchungen über die Galle, &c. Frankfort, 1847.

† Annalen der Chemie und Pharmacie von Liebig und Wohler, Feb., 1846.

ly slightly. They form nearly similar compounds with the alka-, earthy and metallic oxides; but their salts of baryta differ; e fellinate of baryta being soluble in alcohol, the cholinate of ryta insoluble. The product called by Berzelius *dyslysin*, is tained by boiling these acids for a long time in hydrochloric acid. is dissolved with difficulty in boiling alcohol, and on cooling pre-pitates an earthy powder. *Fellinic* and *cholinic* acids have the roperty of combining and forming acid compounds with undecom-sed bilin; these have been named by Berzelius, *bili-fellinic* and *bi-cholinic* acids.

According to Berzelius and Mulder, bilin begins to undergo these anges in the gall-bladder of the living animal; and it is, probably, is proneness to change on the part of its principal constituent hich makes the analysis of bile so difficult, and gives rise to so much iversity of opinion among chemists.

The *fat* of bile exists partly in combination with soda, as oleate nd margarate of soda, and principally as a peculiar substance found nly in bile and in the nervous matter, namely, *cholesterine*. This separable from the other constituents of the bile by agitation in her, which dissolves it; from this solution it crystallizes in plates. exhibits, when pure, the white crystalline lamellated structure of ermaceti, from which it differs, however, in requiring a much igher temperature for its fusion, namely 278°, and in not forming soap with potash. Its formula is $C_{37}H_{32}O$. Cholesterine is the rincipal constituent of the gall-stones most commonly met with in e biliary passages.

The *colouring-matter of bile* (*cholepyrrhin*, Berzelius) is one of s most interesting constituents. It varies in different animals, and erhaps in the same animal at different times, according to the ate of health. Like bilin it decomposes very readily, and there-re cannot be obtained pure; but it has been procured for analysis om the gall-bladder, where it is sometimes deposited as a yellow ibstance mixed with mucus. It is very sparingly soluble in most uids; scarcely at all in water, and very little in alcohol. Its best lvent is a solution of soda or potass. Such a solution, containing e colouring matter of bile, becomes green on exposure to the air, nd on the addition of an acid precipitates green flocculi, which ossess all the properties of chlorophyll, the green colouring-matter f plants. To this precipitate Berzelius has given the name *biliver-in*. The most remarkable property of the colouring-matter of ile is the play of colours which it is capable of producing under he influence of a mineral acid, especially nitric acid. A little of his acid, added to bile, or to a fluid in which its colouring-matter is issolved, as it often is, in urine, will change the colour into blue, reen, violet, red, and ultimately brown, in a few seconds. It is ighly probable, as some chemists affirm, that there exists a great nalogy between the colouring-matter of the bile and that of the lood: as there is also, most likely, between these colouring princi-les and those of nervous substance, skin, and hair.

In addition to these constituents bile contains *mucus* in consider-

able quantity, to which probably is due its peculiar viscidity. It is derived chiefly from the numerous mucous follicles in the bile-ducts, and from the mucous membrane of the gall-bladder, and perhaps also from the debris of the hepatic cells after they have burst and yielded up their contents. According to Berzelius, the mucus may be separated by filtering the bile, when a considerable portion of it remains on the filter, and if the bile which has passed through be subsequently subjected to the action of alcohol, the remaining mucus will separate; or it may be precipitated by the addition of acetic acid. It is to the presence of this mucus in bile that Berzelius attributes the metamorphic tendency of bilin; and he affirms that if fresh bile be deprived of its mucus, the bilin will continue unchanged for a considerable time.

Among the *saline constituents* of the bile Berzelius enumerates the following: oleate, margarate, and stearate of soda, with chloride of sodium, sulphate, phosphate, and lactate of soda, and phosphate of lime.

Such is the view of the constitution of bile put forward by the celebrated Berzelius, and sanctioned by Mulder. Berzelius remarks that the views which regard bile as a solution of soap, are so far correct, as it contains a small quantity of soap dissolved in it.

The most recent analysis of bile is that by Strecker, made under the direction of Liebig, who denies the accuracy of Berzelius's view, adopting rather that of Demarçay, Dumas, Liebig, and others, that bile is a solution of a salt of soda with an organic substance of an acid nature, which is not a single acid, but a mixture of a nitrogenous acid free from sulphur (*cholic acid*), with a second acid, containing both sulphur and nitrogen (*choleic acid*).

Use of the Bile, and Function of the Liver.—From the anatomy of the biliary organs, as well as from the chemistry of the bile, we learn that, before the venous blood of the intestinal canal and the spleen is allowed to reach the right side of the heart, a fluid very rich in carbon is eliminated from it, and poured into the duodenum. The following questions suggest themselves respecting the uses of this fluid; viz.: is the bile simply an excrement, like the urine? or is it an excrement which also serves some ulterior purpose, such as aiding the solution or digestion of the food in the bowels?

The doctrine that the secretion of bile by the liver, is merely a mode of eliminating carbon from the system, is strongly opposed by the fact that in all the vertebrate classes the bile, instead of being carried out of the system by the most direct channel, as the urine is, is made to pass through nearly the whole intestinal canal, and to mingle freely with its contents. Moreover, the point at which it enters the bowel always bears a pretty definite relation to that at which the pancreatic fluid is poured into it. Either these fluids enter the bowel together through a common opening, as in man, or the bile is poured in *above*, *never below*, the point of opening of the pancreatic duct.

These are capital facts, which must be accounted for by an adequate theory of the uses of the bile. They indicate that the bile

has some use in promoting the changes of the food in the intestines, or in contributing to the general process of nutrition in some other way. It is well known that an obstacle to the free admission of the bile into the intestinal canal is always followed by a greater or less derangement of digestion, and by more or less emaciation. But, as these consequences might arise not so much from the want of a due admixture of bile with the food which is undergoing digestion, as from the accumulation of the elements of the bile in the blood, which must derange all the functions more or less, Professor Schwann, of Louvain, tried some experiments which had for their object to stop the flow of bile into the bowel, and at the same time to provide for its excretion. He tied the common bile-duct in dogs, having first established an orifice of communication between the gall-bladder and the skin, through which the bile flowed out of the body as soon as it was secreted, instead of passing into the bowel. It is plain that if the bile were merely excretory, such an operation should produce no injurious effect upon the animal, as still *excretion* was amply provided for.*

Schwann found that of eighteen dogs operated upon in this way two only survived, and in these the divided bile-duct was found re-established, and the bile had resumed its usual channel. Of the remaining sixteen, ten died of the immediate effects of the operation, and the remaining six lingered on for some time, and ultimately died, without exhibiting any other cause for the fatal termination excepting the absence of bile in the intestinal canal. These six died at periods varying from seven days (in a young dog) to two months and a half, the average being two or three weeks after the operation. During this time they exhibited indications of a very enfeebled nutrition, emaciation, muscular weakness, unsteadiness of gait, falling off of the hairs; symptoms which became more developed the longer the dog survived the operation. The emaciation, indicated by a deficiency of weight, began generally on the third day from the operation. When the dogs licked the bile as it flowed out of the fistulous opening, and thus introduced it into the stomach, the digestion in that viscus was not impeded, nor were the results of the operation otherwise embarrassed, showing that it was capable of being digested by the stomach.

Blondlot makes an objection to Schwann's experiments, that, from his mode of operating, the external opening is apt to close, and thus the excretion of the bile is impeded and the nature of the secretion altered. He adopted a different operation, and provided for the free discharge of bile by inserting a canula in the wound. A dog, treated in this way, lived three months; at first he became very thin, and lost strength; but he recovered his strength, but did not completely gain his condition. It appears, from a private communication made by Schwann to Frerich,† that that distinguished

* Expériences pour constater si la Bile joue dans l'Economie Animale un Rôle essentiel pour la Vie.—*Mém. de l'Acad. Roy. de Bruxelles*, an. 1844.

† Art. Verdauung, Wagner's Handworterbuch. This author states that Nasse operated on a dog in a similar way, and that the animal lived nearly six months.

Professor was induced, by these objections of Blondlot, to repeat his experiments, which he did to the number of thirty, and he took the precaution of keeping a canula in the wound. The animals died as before, but one lived a year, another four months; immediately after the operation they lost weight, but after a time the emaciation ceased, and the dogs recovered, but never reached their weight previous to the operation.

The results of these experiments denote that the bile cannot be exclusively an excretion, and, taken along with the facts already referred to, make strongly against this doctrine. But as the excrements of all or nearly all animals, and also the meconium, or the feculent matter found in the bowels of the fœtus in utero, contain in certain proportion the elements of the bile, we are bound to infer that *a portion* of the bile is thrown out of the system, along with the refuse or undigested parts of the food. And that only *a portion* of it, and that a small one, is thus excreted seems evident, because the quantity of bile contained in the feces bears a very trifling proportion to the amount secreted. Thus, Berzelius found only 9 parts bile in 1000 parts of fresh human feces; if we take the average quantity of the feces expelled in the day to be five ounces, this would yield about twenty-one grains of dried bile, equivalent to 210 grains of fresh bile; but the lowest estimate of the quantity daily secreted by the liver is between six and eight ounces, which exceeds that of the feces discharged.

If, then, it be admitted that only a certain portion of the bile is excrementitious, it remains to inquire what becomes of the remainder, and what purpose it may serve?

Liebig suggests that it is absorbed from the intestine, and carried into the circulation, where, by chemical union with the oxygen introduced in respiration, it forms carbonic acid, and generates heat. The liver, according to this view, secretes from the venous blood a material, which, on reabsorption, serves as food for the calorifacient process. It is not likely that this absorption takes place by the veins, for if so, we should find the secreted material carried back again through the very same vascular channels from which but a short time previously it had been secreted; an arrangement which has no parallel in the animal economy. It is more probable, assuming this view to be correct, that the portion of the bile absorbed is taken up by the lacteals; and if so, we should have an additional indication that only a part of the bile re-enters the circulation, for if the colouring matter were absorbed by the lacteals it would be readily detected in the chyle.

There are some striking facts which denote a connection between the office of the liver and the calorifacient and respiratory function. Thus, in the boa, although the liver is large, and no doubt secretes bile freely, the excrements contain no trace of bile. In this case, therefore, it must undergo complete decomposition in the intestine, or be entirely absorbed. In carnivorous animals, whose respiratory function is very active, little or no bile is found in the excrements: while in those of the herbivora, which lead less active lives, and whose

food is more combustible in its nature, the elements of the bile are present in considerable quantity.

According to this view, the bile would be in part excrementitious and carried off in the feces; and in part recrementitious, inasmuch as by its absoption into the blood it serves to feed a process highly important to general nutrition, namely, that of animal heat. Still, there seem strong grounds for supposing that it must serve yet another purpose; else why should the intestinal blood charged with some of the combustible materials derived by absorption from the digested food be subjected to the action of the liver in order to yield a complex fluid, which is poured into the intestinal canal. In truth, we can find no explanation of this remarkable course of the intestinal venous blood, nor of the situation at which the secreted fluid, the bile, is discharged from the liver, but in the hypothesis that the bile has some function to perform in the intestinal canal.

This leads us to inquire whether the bile has any power of reducing certain elements of food which have been only partially or not at all dissolved in the stomach.

We have as yet no satisfactory observations which lead to any positive conclusion upon this point. A series of careful experiments as to the influence of bile upon alimentary matters is much needed. Hunefeld's experiments* on this subject tend to establish the general fact that fibrinous and albuminous matters do seem to be dissolved under its influence at a temperature equal, or nearly so, to that of the blood.

The connection of a gall-bladder with the liver in most animals in which the bile accumulates until intestinal digestion begins, evidently associates the use of the bile with that process.

Sir Benjamin Brodie advocated the doctrine that the bile precipitated the white chyle from the chyme, and was necessary to the formation of the former. He tied the common choledoch duct in young cats so as to prevent the passage of bile into the intestine; and he found that under these circumstances *white* chyle was not formed, the lacteals being filled with a material apparently identical with lymph.† Tiedemann and Gmelin experimented on dogs, and, although they affirm that chyle was formed in the intestine (the accuracy of which statement must not be completely relied upon in default of microscopical examination), yet they admit that the contents of the lacteals in the dog operated on consisted of "a transparent liquid, *not white*," while in the dog not operated on it was white.

By our own experiments we have ascertained that the formation of white chyle took place, notwithstanding the closure of the common bile-duct, provided the animal took a sufficient quantity of *fatty matter* in its food. When this was not attended to, white chyle was not obviously formed. But the most remarkable effects of the ligature of the common duct were the emaciation, loss or capriciousness

* Quoted in Valentin, Physiologie, b. i. p. 349.

† Quarterly Journal of Science and the Arts, 1823.

of appetite, and the general debility which immediately ensued upon it. Hence, although we do not subscribe to the doctrine that the presence of bile in the small intestines is essential to the formation of white chyle, we readily believe that its exclusion from the bowels retards and impairs digestion.

When the biliary duct is obstructed, and the bile does not pass through its ordinary channels, the organs which suffer most disturbance in their functions are the kidneys; as if, when the liver fails in its action, these organs took on the work of eliminating a certain portion of the bile. They secrete urine loaded with the colouring-matter of the bile; and, at the same time, lithic acid, or lithate of ammonia, or purpurate of ammonia (muroxid), is formed in considerable quantity. In cases of jaundice from obstruction, so long as plenty of bile, or its colouring principle, appears in the urine, and a normal quantity of urine is secreted, no very serious symptoms arise; but as soon as the kidneys fail, then indications of poisoning either by bile or urea, or both, arise, and the patients die in a comatose state.

It is worthy of remark that the hepatic cells contain more or less of oily fat: and that under some circumstances this fat accumulates in them to a great extent, so as to occasion enormous enlargement of that organ. And in some fishes the liver is naturally, at certain periods, loaded with it. It is a point of great interest to determine, whether this fat simply accumulates in the hepatic cells, as it does in other tissues, or whether it may not be regarded as a part of the secretion of the liver; in other words, can it be a part of the office of the liver to recombine certain elements of the absorbed food, and to form fat, which, on being discharged into the intestinal canal, is absorbed by the villi?*

In connection with this subject we may refer here to a remarkable fact lately brought to light by Bernard, which denotes that chemical changes take place in the blood while it is passing through the liver, whereby a material is generated in it which had not been introduced in the food.

Bernard has found that sugar is developed in the hepatic capillaries, even when it is not present in the intestines, or in any of the tributary veins of the vena portæ. A dog, which had been fed some hours previously on substances destitute of starch and sugar, was quickly killed, the abdominal cavity was immediately opened, and ligatures were placed on the mesenteric, splenic, and pancreatic veins, and on the trunk of the vena portæ. Blood collected from each of these sources, on the distal side of the ligature, proved on examination destitute of sugar in all, except the vena portæ, in which it was readily detected. Sugar was also found in the tissue of the liver itself. If, then, sugar exists in the vena portæ, but not in its tributary veins, how does it get to the former? As it exists

* It is true that the fatty matter of the bile is not free; but it may be supposed to form its combinations after it has been discharged from the hepatic cells, and while it is passing through the ducts of the liver.

a the tissue of the liver, it is evident that it passes to the vena cartæ by the reflux which, in the absence of valves in the portal ystem, may take place after death. Hence it is reasonable to infer hat sugar is formed in the hepatic capillaries, and carried by the epatic veins to the right side of the heart, in the blood of which Bernard states that sugar is constantly present, whatever food the nimal may have been fed on, and even after a long fast.

The evidence of the presence of sugar in the liver is obtained in he following manner: a portion of the liver is beaten in a mortar, nd then boiled in a small quantity of water, and filtered. The ltered liquid possesses all the properties of a saccharine fluid; it ecomes darker on being boiled with liquor potassæ, and the addition f the tartrate of potass and copper causes a precipitation of the rown oxide of copper. Yeast added to it at a certain temperature auses fermentation; and alcohol may be obtained from the fermented uid by distillation.

There can be no doubt, then, that sugar is formed in the capillaries of the liver independently of the food; it is equally certain hat fat is separated at the same point, for it appears in the hepatic ells; this, too, is doubtless the result of chemical changes in the epatic circulation, independent of the food, because we find good rounds for concluding that the fat of the food, emulsified by the ancreatic fluid, is absorbed by the villi, and does not reach the iver.

Thus are formed in the laboratory of the liver these two products —fat and sugar, very nearly allied in chemical constitution. The ormer is carried into the intestine with the bile, and there absorbed, with the fat of the food, by the villi. The latter is carried by the hepatic veins to the right side of the heart, and thence to the lungs; and both appear to be formed by the liver, whether they have existed in the food or not.

What, then, it may be asked, can be the object of the formation of these products by the liver? If it be to feed the calorifacient process, then the additional question arises, why should each pass to the right side of the heart by a different route?

It seems to us that there is in these arrangements distinct indication of a provision for the *slow* and *gradual* transmission to the lungs of these carbonaceous elements; in order to guard against the blood in these organs becoming surcharged by them so as to interfere with the due introduction of oxygen.

It seems necessary for health that the blood should be supplied, on the one hand, duly, but *gradually*, with carbonaceous matters, such as sugar and fat, and, on the other hand, with oxygen; when the former elements are deficient, fever is the result, the elements of the tissues are consumed by the devouring element, oxygen; and hence it is that we often see such striking results from the gradual ntroduction of alcohol, or other carbonaceous matters, into the system; but when the latter element is deficient, the great vital changes of the blood are delayed, or suspended, and death rapidly ensues. And in the various diseased states of the body there are

infinite shades of difference, as regards the supply or the defect of these great elements; either too much carbon or too much oxygen; or the one is normal in amount, while the other is deficient. A common result of the too ready assimilation of carbonaceous matters, or the too rapid formation of them, is the deposition of fat in various parts of the body, sometimes to the augmentation of its bulk by an increased development of the adipose tissue, at others, to the production of various abnormal deposits, containing more or less fat, as atheroma.

In conclusion, the following propositions will serve to exhibit at a glance all that we may, in the present state of our knowledge, affirm respecting the function of the liver:—

1. That it secretes a highly complex fluid, which is poured into the intestinal canal, and there undergoes decomposition. Its colouring-matter (cholepyrrhin, or biliverdin) is carried off in the excrements, and may possibly assist in stimulating the action of the intestine. Its fat is in great part, at least, absorbed by the villi. So much of its fat as is not thus acted upon contributes to form the feces. Its salts, also, are probably carried off in the feces. Other of its elements contribute to the digestive process, by promoting the solution in the bowels of some kinds of food which have escaped the solvent action of the gastric fluid. What these elements are, and what kinds of food they serve to dissolve, we have yet accurately to determine; it seems certain, however, that it exercises no solvent power over fatty or oily matters, and probable, that it acts upon azotized matters.

2. The liver forms sugar and fat by chemical processes in its circulation, independently of any direct or immediate supplies of these substances in the aliments.

3. The liver is a great emunctory; it eliminates carbonaceous matters, some directly, as the colouring-matter of the bile, which is at once thrown out in the feces; others indirectly, as fat and sugar, which, passing to other parts of the circulation, are more or less acted on by oxygen and eliminated as carbonic acid and water.

4. The liver contributes largely to the maintenance of general nutrition; first, by aiding in the solution of certain aliments in the intestinal canal, and secondly, by furnishing food to the calorifacient process.

Before we leave this subject, we must refer to the remarkable observations of Weber, confirmed by Kölliker, respecting the extensive generation of blood-corpuscles in the liver of the embryo, which have led the former physiologist to form the opinion that "not only is the liver an organ for secreting bile, but that in it a material is separated and accumulated from the blood, out of which blood-corpuscles are formed, which are taken off by the bloodvessels, while from the residuum the bile is formed, which is conveyed away by the biliary ducts."

During the latter days of incubation of the hen's egg, the liver assumes a completely yellow colour, instead of the reddish-brown which it had previously. This is connected with the rapid absorp-

ion of the yelk, probably by the bloodvessels of the yelk-sac, which arry it to the liver, where it finds its way from the bloodvessels into he fine gall-ducts, which at this time are full of particles exactly he same as the yelk-globules. These particles are not carried into he intestine along the biliary passages, but undergo a change by which, on the one hand, blood-corpuscles are formed and pass into he bloodvessels, and, on the other hand, bile is generated and carried ff by the ducts.

Weber states that he has observed a similar phenomenon in the iver of the frog in the spring of the year, when the sexual organs re highly developed, and when the lymphatic system is in a highly ctive state. The liver undergoes a change of colour from reddish-rown to greenish-yellow. It is covered with dark pigment-cells, nd contains numerous opaque masses, which probably consist of the olouring-matter of the bile, which may have accumulated during he winter, but which now undergo gradual solution and pass off in he bile. The peculiar colour which characterizes the liver at this ime, in the frog, is resident, as with the chick, neither in the blood-essels nor in the hepatic cells, but in the minute ramifications of he gall-ducts, which are filled with numerous small globules con-aining fatty particles. These undergo the same metamorphoses as hose of the chick into blood-corpuscles.

This highly interesting subject requires further investigation—to scertain whether similar phenomena may be noticed in other nimals, as in intra-uterine life in Mammalia—or in hybernating nimals—or whether, indeed, they may not be constantly occurring in adult animals, although with less activity than in the young.

The question occurs to us, may the liver be a source of supply of blood-corpuscles, or may it contribute to the production of hæmatine in adult life? It has often struck us that this question might be answered in the affirmative, while observing cases in which the pro-cess of the formation of blood seemed greatly perverted, where no organic disease could be detected beyond some degree of enlarge-ment of the liver. Patients suffering in this way are pale, as if from loss of blood, although no such loss had been experienced; their nutrition is enfeebled, digestion impaired, and there is slight yellowness of the complexion, as in cases of hepatic disease, and after death no lesion is discoverable, but slight enlargement of the liver.*

We have already remarked that the venous blood of the spleen passes along with that from the stomach and intestines through the liver. Recent researches of Kölliker and Ecker offer some expla-nation of this fact, and at the same time of the relation between hæmatine and the colouring matter of bile, as well as between the office of the liver and the generation of the red particles of the blood. It would appear from these researches, which will be detailed when we come to treat of the spleen, that the red blood-corpuscles undergo decay in the red substance of the spleen, giving up their

* Kölliker über die Blutkorperchen der Menschlichen Embryo und die Entwick-elung der Blutkorperchen der Saugethieren.

hæmatine in an altered form to the portal blood, from which it may not improbably, as Kölliker conjectures, pass into the bile-cells to form, and to be eliminated as the biliary colouring matter; and, perhaps, also to contribute to supply hæmatine to new blood-cells developed in the liver.*

Of Digestion in the Large Intestine.—The contents of the large intestine, which constitute *the feces*, properly so called, differ much from those of the small intestine. Generally, and in the normal state, they are more solid, more homogeneous, exhibiting a certain form, which is determined by the size and shape of the cells of the colon. These characters are more marked the further the feces have advanced in the colon.

The changes, upon which depends the difference of character of the contents of the large and small intestine, commence in the cæcum. Many facts lead to the opinion that the intestinal contents undergo some further digestion in the cæcum, analogous to that of the stomach. Schulz affirms that an acid fluid is secreted by the mucous membrane of the cæcum, which is more distinct in herbivora than in carnivora; Bernard and Blondlot state that the acidity of this fluid is due to the presence of lactic acid.† In dogs, we have found that litmus applied to the surface of the cæcal mucous membrane became reddened in some, but not in others; a difference probably depending upon some peculiarity in the food or the time of digestion. The remarkable development of the cæcum in some animals as compared with others, denotes that it must exercise some special function. In herbivora, its size is especially large; in carnivora, it is small. Moreover, the mucous membrane of the cæcum resembles in structure that of the stomach, and is supplied with glands like the solitary glands, which pour out an abundant secretion.

No material change takes place in the feces as they pass through the large intestine, excepting such as is produced by the absorption of fluid from them by the mucous membrane. Thus the feces become drier the longer they remain in the bowels.

Defecation.—The contents of the large intestine are pushed onwards by a vermicular action, essentially the same as that of the small intestine. Propelled thus in successive portions, they accumulate in the rectum, whence they are prevented from escaping by the contraction of the sphincter. The act of expulsion of the feces from the rectum, the act of defecation, is effected partly by the contraction of the muscular fibres of the rectum, excited by the stimulus of distension, and partly by the contraction of the abdominal muscles and of the diaphragm, which, by reducing the size of the abdominal cavity, and compressing the intestinal canal at all points, greatly assists the detrusive efforts of the rectum itself.

Within certain limits the act of defecation is favoured by the bulk of the intestinal contents. When the rectum is moderately distended, and its inner surface sufficiently lubricated by mucus, defecation is effected with but little aid from the abdominal muscles, and mainly by the expulsive force of the rectum, which is sufficiently

* Cycl. Anat. and Phys.; art. Spleen.

† Gazette Méd. de Paris, 1844.

ıg to overcome the passive contraction of the sphincter. If the ents of the rectum be too bulky, they occasion over-distension e gut, and diminish its contractility. Under such circumstances ense accumulations may take place; and, as small portions may inue from time to time to be expelled, under the influence of the minal muscles, the practitioner may thus be deceived as to the nature of the case. On the other hand, when the feces do not mulate in the rectum in sufficient quantity to distend the rec- the act of defecation is rendered difficult by the imperfect ns of the rectum itself, and great efforts are required on the of the abdominal muscles, which often cause the protrusion of ons of the mucous membrane near the anus. Under these mstances it is that enemata act so favourably, by giving the its natural stimulus, that of distension. The action of the ab- nal muscles in defecation is chiefly voluntary, but partly reflex. e rectum be the seat of irritation, as in dysentery, the reflex n is much increased, and the repeated strainings which occur g the act of defecation in this disease are, in a great measure, caused.

e ordinary expulsive actions of the rectum are due simply to timulus of distension acting upon the circular muscular fibres. n the mucous membrane is irritated, as under the influence of a ative, or in diseased states, the action of the rectum takes on character of a reflex act, excited by the contact of the feces the irritable mucous membrane.

e quantity of the feces is determined partly by the quantity quality of the food, partly by the quantity of the secretions ed into the canal. If the food exceed much what the aliment- anal can reduce and absorb, the quantity of feces will be con- able. Vegetable food produces a greater amount of feces than al, because the former is eaten in greater quantity than the r, and because it contains much that is incapable of reduction e stomach or bowels. The feces of carnivora are always abso- y and relatively smaller in quantity than those of herbivora. those tribes of mankind who feed chiefly on vegetable food large quantities of feces.

e ordinary quantity of feces passed daily by men in health, is t five or six ounces; so that, if we assume thirty-five ounces as t the average quantity of food taken in twenty-four hours, it be inferred that at least thirty ounces are appropriated to the us purposes of the economy.

rzelius's analysis of feces gives the following result:—

Water			73.3
Matters soluble in water:	Bile	0.9	5.7
	Albumen	0.9	
	Extractive	2.7	
	Salts	1.2	
Insoluble residue of the food			7.0
Insoluble matters derived from the intestinal canal, as mucus, biliary resin, fat, and a peculiar animal matter			14.0
			100.0

The ashes of human feces yield, according t
lin, chloride of sodium, sulphate of soda, trib
phosphate and sulphate of lime, phosphate c
of iron, and silica. The nature and quanti
ever, vary with the quality of the food.

A remarkable property of the feces is thei
what this depends has not yet been satisfa
seems very doubtful that it can depend on an
bile; for under certain circumstances, when
sent, the fetid odor of the discharges fro
greatly increased, as in jaundice from ob
cholera. It is not improbable that some o
may secrete a peculiar odoriferous principle,
by the bile. Peyer's glands may perform th
derives support from the fact that in cert
glands are diseased, as in fever and phthisi
is increased considerably.

Certain gases are generated in the course
These are partly set free during the change
matters undergo in the intestine; and part
secretion from the mucous membrane. Th
acid, hydrogen, carburetted and sometimes
and nitrogen. A certain quantity of these
tending action, to favour the vermicular m
and so to promote the passage of their con
limits, therefore, the formation of gases in
sumed to favour health; but it is well kn
fluence of emotion, or of irritation, or of cert
are generated in the stomach, as well as i
enormous extent. Tympanites shows itself
influence of strong emotion; and sometimes
fice to generate a quantity of gas sufficien
canal. Also, in fever, the formation of gase
prominent symptom, giving rise to that stat
known to be an unfavourable sign in that dis

On the subjects discussed in this chapter, the rea
writers at the end of the last chapter, and to those quo
the following: Berzelius, art. Galle, in Wagner's Handw
Pancreatique, &c., Arch. Gén. de Méd. 1849; Bernar
l'economie animale, Arch. Gén. de Méd. 1848, and tran
for 1849. Frerich's art. Verdauung, in Wagner's Handw
which did not reach us until this chapter had been so
and Sandras, Comptes Rendus, 1845; Dr. Allen Thomp
Glands, in Goodsir's Annals of Anatomy and Physiology

CHAPTER XXVI.

OF ABSORPTION.—EXAMPLES.—ANATOMY AND DISTRIBUTION OF THE ABSORBENT VESSELS AND GLANDS.—ORIGIN OF THE ABSORBENTS.—PROOFS OF ABSORPTION.—CONTENTS OF THE ABSORBENTS.—ANALYSIS OF CHYLE AND LYMPH.—THEIR QUANTITY.—MECHANISM OF THE ABSORBENT PROCESS.—THE INFLUENCE OF THE QUALITIES OF THE FLUIDS.—OF THE POROUS SOLIDS.—OF PRESSURE.—OF MOTION OF THE FLUID WITHIN THE VESSELS.—CONCLUDING OBSERVATIONS ON THE FUNCTION OF THE ABSORBENTS.

THE function of absorption is universal in organized bodies, as they all live and grow by absorbing suitable material from without and making it a part of themselves. All the tissues are more or less porous, and capable of absorbing fluids brought into contact with them. The cuticle of the hands soaked in water become soft and swollen from the imbibition of that fluid, and if a soluble salt be added to the water, this salt may, ere long, be detected in distant parts of the body by its appropriate tests; showing that the foreign substance has penetrated within the cuticle so as to reach vessels capable of diffusing it throughout the frame.* In the same way soluble substances taken into the mouth, and brought into contact with the alimentary mucous membrane, are rapidly absorbed, either immediately, or after having been first changed and adapted for absorption by the processes described in the preceding chapters. In a similar way gases or fluids effused or injected into the cavities or interstices of the body may be gradually taken up and removed, as we see in cases of emphysema, of ecchymosis, of dropsy, of inflammatory products, &c. An absorption of the tissues themselves is also constantly going on, as a necessary part of their nutrition—the old materials being taken away when no longer suited for the purposes of life. When the effete matters of the tissues are thrown off from the surface of the body, or from glands which are, in fact, a portion of that surface, they are said to be secreted; when they re-enter the circulation for a time they may be rightly said to be absorbed. In certain cases, entire organs waste when the term of their usefulness has expired, *e. g.*, the mammary and spermatic glands, and all the

* Mr. Erichsen took advantage of a case of extroversion of the bladder to experiment on the rapidity of absorption under different circumstances, as indicated by the presence in the urine of the absorbed substances. The following are some of his results. Prussiate of potass taken into the stomach, after a fast of eleven hours, may be apparent in the urine in one minute; but if immediately after a meal, not till thirty-nine minutes. Vegetable infusions required more time for passage through the system. Galls, uva ursi, madder, rhubarb, logwood, &c., passed in from sixteen to thirty-six minutes, according to the time after a meal. Citrates and tartrates of potass and soda rendered the urine alkaline in from thirty-six to forty-eight minutes. When the *feet were immersed* in a pail of water containing three ounces of acetate of potass in solution, the urine became alkaline in sixty-seven minutes; but no effect seemed to be produced when a solution of citrate, tartrate, or prussiate of potass was employed (see *Med. Gazette*, June, 1845).

organs, even the bones, tend to atrophy in advancing life. Again, periodical absorption of the materials of certain organs occurs, as in the testes of birds and other animals after the annual season of impregnation, but perhaps the most remarkable example of absorption belonging to this head, is that of the fat which is stored up in large quantities in the bodies of hybernating animals, and gradually disappears during the winter torpor, probably to furnish materials for the generation of warmth.

These general observations will suffice to show the importance of the subject of absorption. We are led to it, at the present stage, by having to consider the mode in which the materials introduced into the alimentary cavities are conveyed thence to mingle with and form part of the common mass of the circulating fluid. But we may conveniently treat of the process in general in the present chapter.

The coats of the intestine are found to contain two sets of vessels, one through which blood circulates, from arteries to veins through the capillary network, the other containing a milky or transparent fluid, chyle or lymph, which finally reaches the blood. Both of these kinds of vessels are the agents of absorption, and both probably share in receiving the alimentary matters through the mucous lining of the canal, but in the present chapter the structure of the latter will be chiefly considered, and that of the bloodvessels deferred. Together with the lacteals, the lymphatics will be also described.

The lacteals and lymphatics together form one system of vessels, which takes its rise in the midst of various organs of the body, and conveys a fluid into the veins near their termination in the heart. The lacteals constitute that portion of this great system which originates in the digestive mucous membrane, and they are undoubtedly concerned in the absorption of a part at least of the nutrient matters of the food—their contents (*chyle*) after a meal being of a milky appearance—whence their name, *vasa lactea*, given to them in 1622 by their discoverer, Asellius. The lymphatics (and the lacteals during fasting) contain a pellucid fluid—the *lymph*.

The *lacteals* originate in the mucous membrane of the intestines, especially in the villi, and form a network with close meshes in the submucous areolar tissue. There are also more superficial ones between the peritoneum and muscular coat, which take a more longitudinal course, and join the others on the mesentery. They then pass in great numbers between the layers of the mesentery towards its root, anastomosing with one another and traversing glandular organs, the *mesenteric glands*, in their way to the right side of the aorta, where they all finally discharge themselves into an elongated pouch common to them and to the lymphatics of the parts below—termed the *receptaculum chyli*. From this the *thoracic duct* leads upwards to the left subclavian vein.

The receptaculum is usually from an inch to an inch and a half in length, and from a quarter to three-eighths of an inch in diameter. The thoracic duct, which is continued upwards from it, lies in the

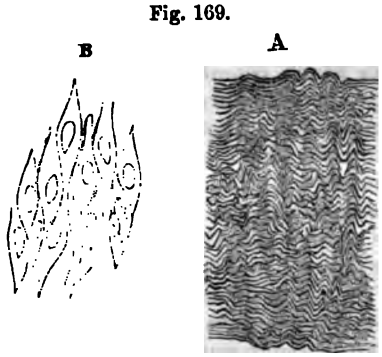
between the aorta and vena azygos, then inclines behind the ıf the aorta to the left side, and empties itself into the upper ack part of the left subclavian vein close to the internal jugular its orifice being defended by two valves. The thoracic duct ut an eighth of an inch or more wide, becomes more narrow the sixth dorsal vertebra, and again dilates opposite the third. quently divides into branches which reunite—and sometimes into the subclavian vein by two or even three separate trunks.

› *lymphatic vessels* of the upper and lower extremities form ets, a deep one accompanying the deep bloodvessels, and a icial one running in the deeper layer of the superficial fascia. sets anastomose and pass in common to the trunk by the groin cilla, where numerous glands occur upon them. (1) Those of wer extremities, after passing under Poupart's ligament, follow eat bloodvessels, are joined by others from the pelvis, loins, bdominal walls and viscera, and open into the *receptaculum* by from four to six large trunks. Very numerous glands suc- ach other in their course, forming an irregular chain. The ic duct is joined by lymphatics from the left side of the walls chest, and from the heart and left lung, on all of which glands occur; and as it empties itself into the great vein, mphatics of the left upper extremity, and left side of the and neck come to meet it. (2) The lymphatics of the right f the chest, of the right arm, and of the right side of the neck ead, crowd towards the junction of the right subclavian and r veins, and open into the former, usually by a large but trunk. The number of lymphatic glands in the whole body e estimated at from two to three hundred, or even more. general, but especially in the limbs, the lymphatic vessels form trunks of equal diameter, taking the same direction, and join- nd again dividing irregularly, without altering their size. In s they differ remarkably from the ordinary arrangement of the iferous vessels.

› absorbent vessels differ from the bloodvessels in the delicacy mitransparency of their coats, which allow the nature of the its to be seen through them; the white colour of the chyle in cteals or mercury artificially thrown in, is at once visible from itside. When the vessels are filled we observe many constric- depending on the existence of valves in the interior, so placed prevent a retrograde flow of the chyle or lymph. These valves oser together in some parts than in others. In general, they rther apart in the narrower vessels, but in the thoracic duct, rgest of all, they are unfrequent. They are usually closest vessels of medium size, *i. e.*, in those of from $\frac{1}{12}$ to $\frac{1}{18}$ of h diameter, but they are not so near to one another in the atics of the upper extremities, and the head and neck, as in of the lower limbs. Besides occurring in succession in the of the vessels, they are almost always found at the origin or ation of branches, and also where the lymphatics empty them- into the veins.

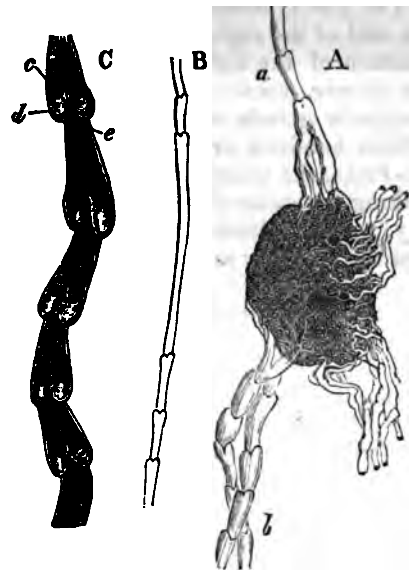
The absorbent vessels have a proper coat, an outer investment of areolar tissue, and an inner lining of epithelium. (1) The proper coat is formed chiefly of circular fibres, relatively most abundant in the smaller vessels, analogous to the contractile tissue of the bloodvessels, and a modification of the unstriped muscle, containing elongated nuclei. On the inner side of the circular fibres are longitudinal fibres, more resembling white fibrous tissue (Fig. 169, A). (2) The fibres of the areolar coat have an irregular course, and blend with the neighbouring tissues. This coat allows of slight movements of the vessel, and contains the blood-vessels which ramify in considerable abundance on the proper coat. (3) The epithelial lining consists of a single layer of extremely delicate nucleated particles, first noticed by Henle. They are usually spindle-shaped, and fitted sideways to each other (Fig. 169, B).

Fig. 169.



A. Longitudinal wavy fibres on the inner surface of the contractile transverse fibres of the thoracic duct of the horse.—Magnified 80 diameters.
B. Stratum of nucleated epithelial cells lining the lymphatic vessels.—From a large lymphatic on the trachea of a horse.—Magnified 320 diameters.

Fig. 170.



A. One of the inguinal lymphatic glands injected with mercury. *a.* Afferent lymphatic vessel from the lower extremity. *b.* Efferent vessel. Others are also seen.
B. One of the superficial lymphatic trunks of the thigh.
C. One of the femoral lymphatic trunks laid open longitudinally to display the valves within it. *c.* Sinus between the valve and the wall of the vessel. *d.* Surface of one valve, directed towards the opposite. *e.* Semicircular attached margin of the valve.—After Mascagni.

The valves (Fig. 170, C) are formed by a process of fibrous membrane standing off into the vessel, probably with a covering of the epithelium. They are mostly in pairs, of a crescentic shape, the convex edge attached, the concave free, and when in action constitute a perfect barrier, the wall of the vessels immediately above them being bulged into a sinus, so as to give the canal a beaded appearance when distended. Mr. Lane has observed that some of the valves are single and circular, with a central perforation, and therefore incomplete—while others are unequal in size.

ıtractility of the Absorbent Vessels.—This depends on the con-
e tissue of their proper coat. The property may be demon-
d by mechanically irritating a large vessel, such as the tho-
luct, in an animal just killed—it undergoes slow contraction.
bsorbent vessels continue to propel their contents, even when
ırrent from the primary networks is arrested by pressure, and
ıey seem to do by their vital contractility. As the contents
ce the vessels diminish in diameter. It is usual to find the
ıatics empty and collapse some time after death.

› *lymphatic glands* are, for the most part, flattish oval bodies,
n consistence and light colour, situated in the course of the
ıatic and lacteal vessels, these vessels being styled afferent as
enter the gland, and efferent as they leave it. The glands
rom the size of a millet-seed to that of an almond. They
y lie loosely in the areolar texture, well protected from injury
ıir mobility, and if near the surface of the body, by the dispo-
of the neighbouring bones or muscles. They have a firm but
te proper capsule, which is continuous with the outer coat of
ssels, and which sends processes inwards upon the bloodvessels
ymphatics which penetrate the glands.

ı general structure of these glands has long been known, being
lisplayed by mercurial injections (Fig. 170, A). This metal,
thrown into an afferent vessel, shows that this divides into
e branches, most of which spread out over the gland before
ng it, and that the efferent vessels have a similar arrangement
e opposite side. The mercury readily fills the entire gland,
scapes by the efferent vessels. The surface of the gland, when
ied by mercury, exhibits either a very close plexus of tortuous
e vessels, or else a congeries of apparent cells; and while there
een no doubt of the continuity of the internal tracts of the
with both the afferent and efferent vessels, the question has
discussed, whether these tracts are simply convolutions of
, or cellular lateral offsets from channels traversing the gland
nore direct course. Both of these views may possibly be true
ferent cases, or probably the convoluted vessels of the gland
be themselves dilated at intervals into cells which, from their
of package, may simulate detached cavities, as in the well-
n arrangement of the vesiculæ seminales. In confirmation of
ıat view it may be observed, that the tracts of the gland are
ly more capacious than the ramifications of the afferent and
nt vessels which immediately communicate with them.

more important question concerns the changes in the tissues
ng the walls of the afferent vessels on their entrance into the
l, and this has been ably illustrated by Professor Goodsir. He
ibes the outer areolar coat as passing to form the capsule of the
l, and the proper coat to become extremely thin, especially in
eeper parts of the gland. The epithelium, however, becomes
er and more opaque, so as often no longer to transmit the light
r the microscope, and by the action of acetic acid very nume-
nuclei are disclosed in it. He describes the elongated nuclei

in the substance of the (proper) membrane
glandular epithelium rests, and appears to c
lium is in constant decay and renovation, be
into the cavity of the ducts, to mingle with
lymph.*

From the examinations we have made of t
lower mammalia, we are disposed to agree i
this description. The very delicate simpl
nucleated cells lining the lymphatic vessel
becomes in the gland a very thick and rathe
loaded with nuclei, in the debris of which
abundance of nucleated cells of different si
cisely resembling the white or colourless lym
to be described. We lean strongly to the
puscles are set free to a large amount, thou
sively, from the surface of the intra-glan
structure of the lymphatic glands offers man
tomist, and there can be little doubt that
discover peculiarities as yet undetected.

The lymphatic glands are well supplied wi
and veins derived from neighbouring sources
the surface, and penetrate between the ducts
for some distance a sheath derived from th
lary network is probably spread out on th
i. e. in the interstices of the plexus which th
but it cannot be said that the exact relation
the abundant granular matter of the ducts
vocally demonstrated. The capillaries are
large, and they anastomose throughout.

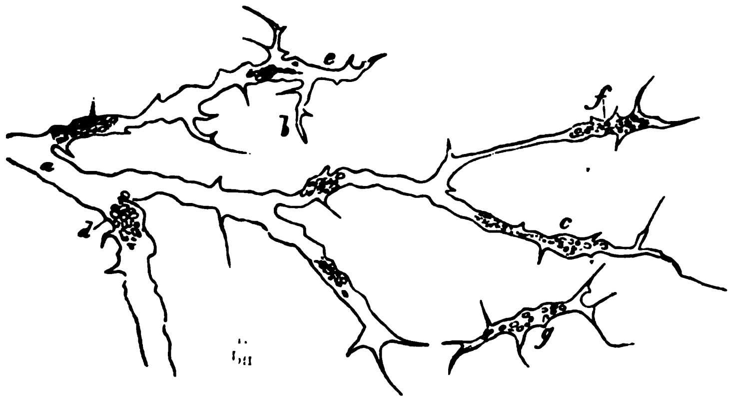
In injections of the ducts of the glands, t
find its way very readily into the veins, but
and it has been concluded by Fohmann, tha
ral communication between these sets of vess
view is certainly rendered plausible by the
the lymphatics in the veins of the neck, a
appears to be established by the observation
and Panizza, that in birds, as well as in re
are communications with the small veins a
pelvis and abdomen. Nevertheless, the evi
munication in the lymphatic glands is ver
more probable explanation of the fact abov
that the brittle texture of the interior of th
way before mercury, and that then the m
more numerous than the arteries and less r
receive the extravasated metal.

Origin of the Lymphatics.—We have befor
the lacteals in the villi of the small intestin
other regions have been usually considered t

* Anatomical and Pathological Obse

of the skin and mucous membranes, and on the surface of the viscera by a plexus of somewhat variable character. In the skin and elsewhere the meshes are very close and small, while on the lungs they are much more open and the vessels larger. The surface of the liver and spleen is overrun with a network of lymphatics of remarkable luxuriance. So far as mercurial injection can inform us, these plexuses are the commencement of the lymphatic system; but we have been recently made acquainted with a system of lymphatic vessels discovered by Kölliker in the tail of the larvæ of batrachian

Fig. 171.



Part of a ramification of a lymphatic of the under part of the tail of a tadpole. *a.* Simple membrane, forming the wall of the vessel. *b.* Prolongation or process of this membrane. *c*, *d.* Fatty granules attached to the inner surface of the membrane, and surrounding the nuclei. *e.* A closed extremity of the vessel. *f.* Branched cell, just united to a corresponding extremity. *g.* Branched cell, on the point of coalescing with a capillary lymphatic vessel already formed.—Magnified 400 diameters. After Kölliker.

reptiles, which renders it probable that a still finer series exists in the higher animals and in man, than those comparatively large ones which compose the plexuses just mentioned. Kölliker observed these vessels during life, and satisfied himself of their continuity with the neighbouring lymphatic trunks. He found them about the same size but less numerous than the blood-capillaries, and composed of a simple, very delicate membranous wall, projecting into small pointed processes, here and there, and containing a few flattened nuclei. The pointed processes may belong only to their rudimentary and not to their completely developed condition. He states that they ramify in an arborescent manner, without anastomosing, and end by free closed extremities. They have no valves, and remain of the same width during life, but after death exhibit the same contractility, though not of so active a kind, as the capillaries, by lessening uniformly in diameter during a certain time. He was able to detect the movement of their transparent contents by that of the granules and lymph-corpuscles, which, in rare instances, they were observed to contain, and found it to be continuous, and very slow, almost twelve times as slow as that of the blood in the capillaries. He found the mode of development of these primary lymphatics to

resemble closely that of the capillaries, *i. e.*, it takes place by the outgrowth and subsequent coalescence and tubulation of processes from contiguous nucleated cells.

Kölliker's observations on the relations of these minute lymphatics with the capillaries are interesting. He found that when the current of blood was regular, there was no appearance of communication between the two orders of vessels, but that when the circulation was excited and tumultuous, owing to the confinement of the tadpole under glass, during the observation under a high magnifying power, red blood-corpuscles escaped more or less readily from the bloodvessels into the contiguous lymphatics; and in several instances he was able to detect actual communications between lymphatics of the finest kind and the network of capillary bloodvessels. After careful inquiry, however, he concludes that these junctions are due to rupture, or, perhaps, in some cases, to a primitive abnormal formation. He further noticed a reflux of blood into the lymphatics through the orifices by which their trunks open into the larger veins. This retrograde current was almost always observed when the respiration was impeded by want of water, and the veins were consequently gorged, or when a ligature was placed round the head. In the latter case, the whole lymphatic tree was often fully and beautifully injected with blood.

A lymphatic system exists in all the vertebrata, but the glands are wanting in fishes and reptiles, and are very few in birds, being found only in the neck. In fishes and reptiles, however, there occur large and intricate lymphatic plexuses, chiefly without valves, accompanying and sometimes completely surrounding the bloodvessels in a luxuriance quite superior to anything found in the higher classes. Moreover, there exists in the course of the lymphatic trunks in these animals and in birds, pouches furnished with valves and muscular walls, which contract rhythmically and urge on the lymph towards the veins. These *lymphatic hearts* are, in birds at least, formed of the striped fibre, according to the observation of Stannius; and we owe to Volkmann the interesting fact that, in frogs, their contraction may be excited by the direct influence of portions of the spinal marrow.*

Do the Lacteal and Lymphatic Vessels absorb?—From the account now given, it is clear that the structure and arrangement of the lymphatic vessels fit them only for the conveyance of fluid in one direction, viz., from the various tissues in which they originate to the great veins, and thence to the heart. Hence there can be no doubt, that, whatever other function they may subserve, they are designed to carry fluid into the blood either from the exterior of the body, as in the case of the digestive mucous membrane and the skin, or from the interstices of the various textures, where it may have been derived either directly from the circulating mass, or indirectly from the waste of the textures themselves. It was till lately assumed too exclusively that this system of vessels was the sole agent in such absorption, and hence the name of absorbent system, as applied to it, and the view which allowed the bloodvessels no share in the absorbent function.

To prove that the lacteals absorb chyle, it is only necessary to

* Paget's Report, 1844–5, p. 27.

nine them in a fasting and in a recently fed animal. In the ier their contents are transparent, in the latter they are milky, the opaque fluid can be shown, by simple means, to move on in course indicated by the valves. That the lymphatics absorb erhaps best shown by the phenomena of disease. The syphilitic on is frequently carried from the primary sore along the lymph-s, and exciting inflammation in this route may occasion de-ts of lymph or pus either on the penis or in the groin, and matter of abscesses so formed is capable of imparting the disease ther individuals, thus proving the multiplication, and probably the real transport of the virus along these channels. The in-mation of the lymphatic trunks and glands, so often observed to le upon accidental wounds, either poisoned or not, especially in litated subjects, seems due to an actual propagation of morbid erials in the current of the lymph, exciting inflammation in suc-ive parts as it comes into contact with them; and the severe titutional disturbance usually attendant on this state of lymphatic mmation is attributable, with a high degree of probability, to a harge of some such morbid fluid contaminating the lymph into bloodvessels, so as to mingle with the general circulating mass lood. Wagner mentions that the axillary glands of a subject ght for dissection were found of an intense red colour from the sition of cinnabar in their texture, while on the arm was a red oed figure of old date, which had evidently furnished the mate-*

hat the bloodvessels also absorb, however, is rendered certain, merely by considering that their structure and physical con-ns furnish every element requisite for this function, but by riments of a conclusive nature. Panizza poisoned a horse, by ining hydrocyanic acid in a loop of intestine, which was sepa-d from the body excepting by one artery and vein which main-ed the circulation in it. As long as the vein was compressed animal escaped, but when the pressure was remitted the poison effect; and, in blood drawn from the vein, the acid was detected.

ontents of the Absorbents.—The lymphatics (and the lacteals when stion is not going on) contain a nearly colourless and transparent, termed lymph, in which are included a number of colourless eated cells of globular shape (*lymph-corpuscles, colourless cor-les*), analogous to, and even identical with, the colourless cor-les of the blood. The lacteals, during the digestion of fatty ers, always contain another element, which gives a milky hue to hyle, viz. a finely granular matter, termed, by Mr. Gulliver, the *cular base.*

ymph and chyle, when withdrawn from their vessels, sponta-sly coagulate into a slightly coherent jelly in the course of a minutes. This property depends on the presence of fibrine in id form, as in the blood, and varies with the point from which lymph is drawn, as well as with the activity of the nutritive

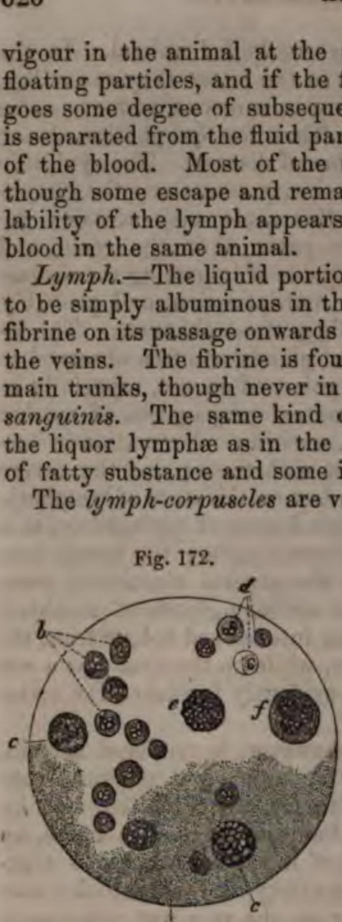
* Physiology, by Willis, p. 440.

vigour in the animal at the time. The clot at first entangles the floating particles, and if the fibrine have sufficient energy, it undergoes some degree of subsequent contraction, by which a loose mesh is separated from the fluid part, as the crassamentum from the serum of the blood. Most of the corpuscles usually remain in the clot, though some escape and remain with the fluid element. The coagulability of the lymph appears to bear a close relation to that of the blood in the same animal.

Lymph.—The liquid portion, *liquor lymphæ*, is supposed by some to be simply albuminous in the primary network, and to acquire its fibrine on its passage onwards through the vessels and glands towards the veins. The fibrine is found in increasing quantity towards the main trunks, though never in so large a proportion as in the *liquor sanguinis*. The same kind of saline matters are also met with in the liquor lymphæ as in the liquor sanguinis, together with a trace of fatty substance and some iron.

The *lymph-corpuscles* are very scanty in the primary network and branches (as already noticed in the observations of Kölliker), and they increase in number, and perhaps in size, towards the trunks, especially as they pass the glands. They present themselves under some varieties; in one, and this is the most usual, the nucleus is concealed by a granular matter; in another this granular matter appears in process of removal or deliquescence, so that the nucleus is visible; or, again, the interval between the nucleus and the cell-wall may be quite clear, and the granular matter wanting. These corpuscles are called, by Mr. W. Jones, respectively the *granule cell* and the *nucleated cell in the uncoloured stage*, and he further points out that there are in the lymph other nucleated cells approximating in colour to the red-corpuscles of the blood, and which he regards as in progress to become red blood-corpuscles, by losing their cell-wall, and becoming reduced to a simple nucleus.*

Fig. 172.



Fluid from a mesenteric gland of a rabbit, when white chyle was present in the lacteals. *a.* Molecular base. *b, c, d,* &c. Various organic corpuscles. *b.* Appearance of the majority of corpuscles. The contained granules are most numerous and coarse in the largest ones, but almost entirely disappear under the action of acetic acid, which thereby discloses an appearance of one or two nuclei. The majority of the corpuscles are either large or small, and but few of intermediate size. *d.* Exhibits the effect of acetic acid in rendering the corpuscles more clear and their nuclei more distinct. *e.* Large lymph-corpuscle, showing well the granulated border. *f.* Large corpuscle, apparently inclosing three smaller ones, each of which has the granulated character. This appearance of inclosed cells is not common.—Magnified 300 diameters.

Besides these true corpuscles of the lymph, it is very common to find in it red blood-corpuscles. These, it is probable, have been accidentally introduced into the lymphatic vessel during the dissection employed to lay it open.

Chyle.—The *liquor chyli* contains more albumen and more fat

* Philosophical Transactions, 1846, p. 82, and the next chapter, on the Blood.

liquor lymphæ. It has been noticed that the lacteals near stine contain little or no fibrine; their contents do not ac- e power of spontaneously coagulating till we approach the nks. Even in the receptaculum chyli and the thoracic duct, ie chyle is commingled with the lymph from distant parts, formed is still much softer than that of blood.

orpuscles of the chyle are the same as those of lymph. In , however, we have in most instances the *molecular base*. ies with the amount of fatty matter in the food. It gives e that milky colour which was shown by Tiedemann and to have a close correspondence with the fat of the food. It n noticed to be generally absent or very deficient in birds; it bundant in herbivorous animals than in carnivorous. If a ed on food from which fat is carefully excluded, the chyle ilky, but whey-like or transparent.

Benjamin Brodie, in 1816, fed a cat on jelly, and a dog on jelly: the animals were killed after two hours. The s were found nearly empty, the duodena filled with a mix- arently of chyle and jelly; the lacteals and thoracic ducts d *transparent chyle*, which coagulated spontaneously. He fed a dog on lard, after a fast of thirty-six hours, and in urs killed the animal. Some lard was found in the stomach, id of albuminous character in the duodenum, the same tinged e in the ileum, and in the thoracic duct perfect *milky*

nolecular base is present in the lacteals from the very com- ent, even from the villi of the intestines. It seems to con- lmost infinitely small particles (Fig. 172, *a*) of oleaginous or tter, thrown into this form by contact with the pancreatic n, as so well proved by Bernard. The particles do not look nder the microscope—their outline is not definite or sharp, n this circumstance, as well as from their extreme minute- is not easy to assign them an exact size. In fact, they vary t. Mr. Gulliver makes their diameter $\frac{1}{36000}$ of an inch. e white colour of the chyle does not depend on precisely the use as that of the milk, for the latter exhibits under the pe myriads of true oil-globules of different sizes. A few les are commonly found in the chyle, but they are probably us.

. O. Rees gives the following analysis of the contents of acic duct of a criminal, who had taken two ounces of bread ounces of meat on the preceding evening, and two cups of a piece of toast an hour before he was executed, and whose s examined one hour and a quarter after death. Nearly hms were obtained, of a milky hue, with a slight tinge of

ctions from Notes of Physiological Experiments," by Sir B. C. Brodie Bart., 9, 40, 41.
Trans. 1842, p. 82.

Water	90.48
Albumen, with traces of fibrine	7.08
Aqueous extractive	0.56
Alcoholic extractive, or osmazome	0.52
Alkaline chloride, carbonate, and sulphate, with traces of alkaline phosphate, and oxide of iron	0.44
Fatty matters	0.92
	100.00

The following is his analysis of the lymph and chyle of the ass:*—

	Lymph.	Chyle.
Water	96.536	90.237
Albumen	1.200	3.516
Fibrine	0.120	0.370
Extractive	1.559	1.565
Fatty matter	a trace	3.601
Salts	0.585	0.711
	100.000	100.000

These latter may probably be taken as fair samples of the constitution of the lymph and chyle. Much variety, however, will of course exist in specimens, derived from different animals, and at different periods of digestion. The chief distinctions between lymph and blood, are: 1st, the absence of the red particles in the former, and, 2d, the smaller proportion of albumen and fibrine. Chyle differs from blood in the same points, and, moreover, in its large proportion of fat, which may rise, according to Nasse, as high as 15 in 1000. Chyle differs from lymph in containing more albumen, and much more fat.

Quantity of Chyle and Lymph.—That the chyle enters the blood very rapidly along the lacteals during digestion is obvious on opening the body of an animal. It is easy to collect from the thoracic duct of a small dog, in the course of a few minutes, as much as will fill a watch-glass. If absorption is actively going on at the moment, a ligature on the duct will often be followed by a rupture of some vessel below by the onward pressure of the current. So the lymph, in some instances, has been collected in considerable quantity in a short space of time. Geiger, from an open lymphatic on the foot of a horse, collected from three to five pounds of lymph daily. Bidder has performed some experiments on cats, from which he estimates that a quantity of lymph and chyle, together equal to one-sixth the weight of the body, or the whole weight of the blood, enters the circulation every twenty-four hours. But it must be borne in mind that this does not all form new supply, the lymph being, probably, in large measure derived from that liquor sanguinis which has escaped from the capillaries into the interstices of the tissues, and which cannot re-enter the capillaries in a direct manner.

Mechanism of Absorption.—In considering this part of the subject, the following points should be remembered:—

1. The process of absorption in living bodies implies *imbibition* by their tissues and subsequent *transmission* of the imbibed fluid by the vascular channels to distant parts.

* Med. Gazette, Jan. 1841.

2. As regards imbibition, it is a phenomenon of a purely physico-chemical nature, ad occurs in inorganic as well as organic bodies, and in organic bodies both when ead and living. It depends mainly on the force of adhesion between a fluid and a orous solid, by which the fluid is drawn into the interstitial passages of the solid.

3. The fluid chiefly concerned in this process in all animal and vegetable bodies is ater, which, as already stated, has a close affinity for their tissues, and forms an ssential ingredient of them, without which they for the most part lose their vital ad physical properties.

4. The various other substances which are imbibed in living bodies are taken up in state of aqueous solution, such as gases, albumen, fibrine, salts, &c.

5. Where the fluid is rendered complex by holding in solution various substances hich have different degrees of the force of heterogeneous adhesion for each other, r the water they are dissolved in and for the porous solid, the phenomena of their ransmission are also complex: various preferences, if we may so express it, exist; ne ingredient penetrates rather than another, and the results depend very much on e chemical qualities of the elements concerned.

6. The laws relating to the mixture of different fluids also exert an important inuence on the phenomenon.

Referring to a former page (p. 67) for a brief notice of the phenomena of endosmose and exosmose, as observed by Dutrochet, we ay conveniently proceed with the consideration of the mechanism f absorption in the living body under the following heads:—

Absorption as influenced by the Qualities of the Fluids.—It was hown by Chevreul, that an animal tissue imbibed very different mounts of different fluids with which it was brought into contact fter it had been dried. Thus the cornea took up water, brine, and l, in the proportions of 461, 370, and 9; and Liebig, in experients with the dried bladder of the ox and pig, has found that "of l liquids, pure water is taken up in the largest quantity; that the bsorptive power for solution of salt diminishes in a certain ratio as e proportion of salt increases; and that a mixture of alcohol and ater is taken up more abundantly the less alcohol it contains."*

The mixture of two dissimilar fluids through a membrane is much fluenced by their respective attractions for the membrane. Thus, s water has a stronger affinity for the membrane than brine or lcohol, it permeates it more readily and arrives in greater quantity a given time on the opposite surface than either of those fluids. Hence more water comes through to mix with the alcohol, than lcohol to mix with the water, and an accumulation of the mixed uids consequently takes place on the side of the alcohol; for the lcohol, or the water, having once traversed the thickness of the embrane, comes into contact with the opposite fluid, and becomes iffused through it in obedience to known laws. The same is true n regard to various substances miscible with water or dissolved in it.

Within the bloodvessels and the lymphatics is a fluid considerably enser than water, and having less affinity for the walls than water. Hence, if water be applied to the surface of the body or taken into he stomach, it readily enters the circulation, particularly in the later case, where it is brought into much closer contact with the bloodessels. If a quart of warm water be injected into a torpid colon, alf an hour will almost suffice to convey it into the bloodvessels,

* Researches on the Motion of the Juices in the Animal Body. Translated by Wm. Gregory, M. D. London: 1848. P. 9.

and thence through the kidneys into the bladder. If, however, the injected water hold a considerable quantity of common salt in solution, it will be absorbed more slowly; while, if the solution be a concentrated one, the fluid portion of the blood will pass out of the vessels to mix with the saline solution. The action of many medicines taken by the mouth, particularly of saline purgatives, is in some measure explained by these laws.

It is interesting to notice that albumen passes less readily through an animal membrane than gelatine, gum, or sugar. Thus alcohol, ether, oil, albumen, gum, and sugar would disappear from the stomach in very different intervals of time.

Absorption as influenced by the Porous Solid.—An extensive and accurate series of experiments has been recently performed by MM. Matteucci and Cima, in which they investigated the influence of different kinds of animal membranes, and of various arrangements of them, on the transmission of various fluids. They employed—1. The skin of the frog, the torpedo, and the eel; 2. The mucous lining of the stomach of the lamb, cat, and dog, and of the gizzard of the fowl; and, 3. The mucous lining of the bladder of the ox and pig. The following are the general conclusions derived from these experiments, in the words of their translator:—

"1st. The membrane interposed between the two liquids is very actively concerned, according to its nature, in the intensity and direction of the endosmotic current.

"2ndly. There is, in general, for each membrane, a certain position in which endosmose is most intense; and the cases are very rare in which, with fresh membrane, endosmose takes place equally, whatever be the relative position of the membrane to the two liquids.

"3rdly. The direction which is most favourable to endosmose through skins, is usually from the internal to the external surface, with the exception of the skin of the frog, in which endosmose, in the single case of water and alcohol, is promoted from the external to the internal surface.

"4thly. The direction favourable to endosmose through stomachs and urinary bladders varies with different liquids much more than through skins.

"5thly. The phenomenon of endosmose is intimately connected with the physiological (natural or healthy) condition of the membranes.

"6thly. With membranes, dried or altered by putrefaction, either we do not observe the usual difference arising from the position of their surfaces, or endosmose no longer takes place."*

With the mucous lining of the stomach of the lamb (whether the paunch or the true digestive stomach is not mentioned) these trustworthy experimenters found that water passed through towards a solution of sugar in greater quantity when the water was at first

* Lectures on the Physical Phenomena of Living Beings. By Carlo Matteucci. Translated under the superintendence of Dr. Pereira. Am. Ed. p. 71.

ın that side of the membrane which is naturally turned to-
ıe interior of the cavity of the stomach, than when it was
ın the opposite side; the proportions being about as six to
'n the contrary, when solution of white of egg was used,
ıssed more readily, when placed in contact with the attached
ucous surface than when in contact with the free or epithe-
'ace. It passed also towards the albumen in only half the
' that it did to the sugar. Again, with a solution of gum,
osmose was very feeble, whichever way the membrane was
–and seemed to follow no rule.

ı facts show the influence exerted by the structure or chemi-
ıerties of the membrane in this process, but we are still very
ı the dark as to the intimate cause of the influence thus
ıg.

are sufficient, however, to indicate the extremely important
ə in physiology, that the chemical and structural properties
ssues exert a great influence on all those processes in which
əcular motion of fluids is concerned.

hickness or thinness of the membrane also much affects the
ınd that for an obvious mechanical reason. If the transmis-
luids is so rapidly carried on out of the body, through the
ıickness of compound and dense membranes, how much more
ous must it be in the living tissues, where the external fluid
eneral but one or two very attenuated films of membrane to
in order to arrive within the capillary bloodvessels.

ption as influenced by Pressure.—The influence of pressure
passage of fluids through membranes is illustrated by a
filter, or by tying a membrane over one end of a vessel
ng fluid, to which a syringe capable of applying various de-
f pressure is adapted. In the latter case, the rapidity of
ısion will be found, *cæteris paribus*, to depend on the degree
ıure employed, and after a certain time the transmission
ıccelerated by the enlargement of the pores of the membrane.
way pressure may be used as a test of the relative transmis-
of different fluids through membranes of various thickness
lity; and Liebig has found that "through ox-bladder, $\frac{1}{120}$
ch thick, water flows under a pressure of twelve inches of
'; that a saturated solution of sea salt requires from eighteen
;y inches; and that marrow oil only flows out under a pres-
thirty-four inches of mercury.

en the membrane used is the peritoneum of the ox, $\frac{1}{310}$
ch in thickness, water is forced through it by eight to ten
ɔrine by twelve to sixteen inches, oil by twenty-two to twenty-
hes, and alcohol by thirty-six to forty inches of mercury;"
ıce it appears, as this eminent writer remarks, that "the
f a liquid to filter through an animal membrane bears no
to the mobility of its particles; for under a pressure which
rater, brine, or oil to pass through, the far more mobile al-
ɔes not pass."

ressure promotes the transmission of fluid through a mem-

brane in one direction, so it tends to interrupt the passage of the other fluid in the opposite direction—or, to apply this to the bloodvessels of the living body, if they are distended by an over-great quantity of blood, so that this fluid reacts upon their inner surface, as in the case of plethora, fluids enter them with difficulty from without — whereas, if their bulk is diminished by venesection, absorption is comparatively rapid. This conclusion was established by Magendie on good grounds, and it has some illustrations and valuable applications in practice.

Absorption as influenced by motion of the Fluid within the Vessels. —Fluid may be raised out of a reservoir against gravity, by directing a stream along a membranous canal, which lies immersed in the stagnant fluid. The outer fluid enters the canal by endosmose, and is carried away with a speed proportioned to the velocity of the current. If the fluid in motion is so compressed as to exert much lateral pressure on the wall of the tube, it will rather itself pass outwards, so as to mingle with the fluid at rest, than receive and carry off the latter. If the fluid in motion is also the more dense, or otherwise, that towards which the external fluid would flow if both were stagnant, then its motion accelerates the endosmose by constantly bringing on fresh fluid of the original density, so that the first rate of transmission is maintained.*

It will be scarcely necessary to state in detail the particular bearing which the preceding considerations have on the question of the mechanism of the absorbent process in the living body. It is, however, very evident that they leave us with little more than some general indications of the lines in which further investigation may be pursued with advantage.

Applying them to the mechanical arrangements provided in the living animal for this function, it is plain that they have a nearer reference to the capillary bloodvessels than to the lymphatics. In both we have a simple membrane of extreme thinness, through which the absorbed fluid has to pass, and in doing so it must necessarily obey those laws which form the proper subject of experimental physico-chemical inquiry. But in the bloodvessels, the fluid on the side towards which absorption tends, is already in motion by a mechanical force, the heart's action, and the absorption is accompanied with a contrary current of exosmose; whereas in the lymphatics, the internal fluid appears to have no motion but what is derived from the same force on which the endosmose depends, and we have no evidence of any outgoing current. In these respects the absorb-

* In a valuable paper by our friend, Dr. Robinson, of Newcastle (*Med. Gazette*, 1844), many experiments and arguments are given to show that absorption goes on rather on the venous side of the capillary network, and in the small veins, than on the arterial side. He considers the motion of the blood to be an influential cause of absorption, by diminishing its pressure outwards on the vascular walls, and thus allowing the external pressure (that of the atmosphere and of the surrounding tissues) to predominate. There can hardly be a doubt that the rapidity of absorption will be influenced by the rate of movement of the blood as well as by other mechanical conditions.

nts resemble, more nearly than the capillaries, the spongioles and bsorbent vessels of plants.

Function of the Absorbents.—A few words may be added on the se of the absorbents in the economy. The *chyliferous vessels* robably have the same office for the intestinal tissues as the lymphatics in other parts; but besides this, they are largely developed, nd specially adapted by their mode of origin on the mucous surface, o take up a portion, at least, of the food, after it has been rendered apable of absorption by the action of the pancreatic secretion. This ortion appears to be pre-eminently the fatty or oily, which, as far s experiments and observation have yet determined, is almost exlusively absorbed by the lacteals. It is chiefly in containing so nuch more fat that chyle differs from lymph.

The *lymphatics* cannot yet be said to have their office at all definiively ascertained, yet it is not difficult to assign them a part with ome degree of probability. It appears that they form an interlacenent among the capillaries in the interstices of most of the organs nd tissues of the body, and contain a fluid not disimilar in kind rom the liquor sanguinis, though more dilute. They cannot be engaged in distributing new material to the organism, because their tructure adapts them only for removing fluid from the tissues, and ouring it into the bloodvessels, and because the current within them s unequivocally in that one direction. Thus the fluid they contain nust enter them from the interstices of the tissues, having been ultinately derived either directly from the capillaries, or indirectly from hem through the tissues. It seems not improbable that the liquor anguinis effused through the capillary walls for the nutrition of the issues, may have its superfluous parts removed through the lymphaics, as it would, perhaps, be more readily received into these new hannels than into the same from which it had just been poured. It s a question quite undetermined, whether the effete materials of the issues are returned to the circulation in any large measure through he lymphatics, or whether they are principally restored to it by irectly entering the capillaries, in exchange for that outgoing curent of renovating plasma which serves to supply the waste in nutriion. The carbonic acid at least, if indeed that product be formed mong the tissues, outside the capillaries, and not in the blood, eems to enter the capillaries in a direct manner through their wall, ince it is found in greater quantity in venous than in arterial lood.

The absorbent system, with its glands, may be regarded in yet nother light, viz., as a great internal glandular or secreting system, he ducts of which open not on the surface of the body, but into the ascular system. It is conceived that the inner surface of the ymphatics, and especially of the lymphatic glands, serves to elaborate and separate from the blood contained in the vessels distributed n their walls a secretion which is set free into their interior, and is ransmitted ultimately to the current of circulating blood through the efferent vessels of the glands, which may be thus looked upon s excretory ducts. Some physiologists attach much importance

to the alleged increase in the quantity of fibrine contained in the lymph as it traverses the absorbent system, and conclude that this is due to the elaborating agency of the epithelial element of the absorbent tracts on the albumen of the lymph. We owe to Dr. Carpenter a very interesting hypothesis on the influence, in this respect, of the colourless corpuscles, which he imagines to exert this catalytic action on the albumen in which they float. This idea will be best considered in the Chapter on the Blood.

On the subjects of the foregoing chapter, in addition to the systematic works on Physiology before referred to, the student may consult Mr. Lane's article "Lymphatic System," in the Cyclopædia of Anatomy and Physiology; Matteucci's "Lectures on the Physical Phenomena of Living Beings," translated by Pereira: and the valuable "Reports" by M. Paget, in the British and Foreign Medical Review. We would also refer to a recent work by Liebig, on the motion of the juices of the animal body, ably translated by Dr. Gregory, from which we have derived much assistance.

CHAPTER XXVII.

THE BLOOD.—ITS QUALITIES.—ITS PHYSICAL ANALYSIS.—THE LIQUOR SANGUINIS.—THE BLOOD-PARTICLES.—THE QUANTITY OF BLOOD IN THE BODY.—THE PHENOMENON OF COAGULATION.—THE CONSTITUENTS OF THE BLOOD.—ANATOMY OF THE BLOOD-CORPUSCLES.—THEIR MODE OF ORIGIN.—THEIR FUNCTION.—THE CHEMICAL ANALYSIS OF THE BLOOD.—CHANGES PRODUCED IN THE BLOOD BY VENESECTION—AND BY DISEASE.

THE blood is a fluid, which is always circulating in numberless canals among the various tissues and organs of the body; it is the source whence those tissues and organs draw their nutriment, and from which the glands derive the materials for their several secretions. The lymph and the chyle are poured into it as tributary streams; the former conveying to it, in solution, materials yielded up by the wear and tear of the tissues, and also derived from without; the latter bringing to it new matter formed by the digestive process.

The blood is a thick fluid, apparently homogeneous, of high specific gravity (1041—1082, Simon), and of a red colour, in all the vertebrate and most of the invertebrate classes, but exhibiting differences of colour, according to circumstances to be noticed hereafter.—A saltish taste, and a peculiar heavy odour, must also be reckoned among its characters. If allowed to rest in a cup, or other vessel, it exhibits a remarkable spontaneous analysis. In the course of from ten minutes to a half an hour it separates into a solid portion (the crassamentum) and a fluid portion (the serum). The latter, if carefully decanted off, will be found to be a clear straw-coloured fluid, the menstruum of that great variety of mate-

ıich is held in solution or suspension in the blood. Albumen ı quantity, salts, and various organic matters, are dissolved ıily matters are suspended in it; and prior to coagulation is held in solution, and coloured and other particles are dif- ı infinite multitudes throughout it.

ırtificial physical analysis of the blood, first suggested by shows satisfactorily the true relation of its various con- s. If the blood of an animal whose coloured particles are e size, as the common frog, be passed through filtering ts liquid portion passes through, leaving the coloured parti- on the filter; thus analysing the blood into two parts—*the anguinis* and *the blood particles*. The former, by the spon- coagulation of the fibrine, quickly separates into serum and which in this instance is colourless, but in the ordinary tion it is more or less coloured by the red particles, which entangled by the coagulating fibrine. Another mode of g a similar analysis is that suggested by Dr. A. Buchanan of r: it consists in mixing fresh-drawn blood with six or eight s bulk of serum, and filtering through blotting-paper: coagu- ı retarded by the admixture with serum, and a great part of ted liquor sanguinis passes through the filter, and subse- coagulates. By microscopical analysis of the blood, we find sides the red particles, it contains others which are devoid ring matter—namely, the *colourless corpuscles*.

ıonstitution of the blood is expressed by the following table:—

$$\text{The blood consists of}\begin{cases}\text{corpuscles; red and colourless.}\\ \text{liquor sanguinis, consisting of}\begin{cases}\text{fibrine.}\\ \text{serum.}\end{cases}\end{cases}$$

the blood has the same essential characters in both the ver- and invertebrate classes, has been shown by Mr. Wharton researches, who finds the coloured and colourless corpuscles ılood of all animals, presenting, however, sufficiently distinct- ures.

ın and the mammalia there are two kinds of blood, distin- by difference of hue, *the scarlet, arterial blood*, obtained e left side of the heart, and from the arteries; and the *black, red, venous blood*, obtained from the right side of the heart, m the systemic veins. We shall consider, further on, the characters of each kind, and the cause of their differences.

ıemperature of the blood ranges between 100° and 105°. tion is slightly alkaline, so that a drachm of blood will satu- her more than a drop of vinegar.

consideration of the natural history of the human blood ı the determination of the following points:—

, the quantity of blood in the body.

ıdly, the phenomenon of coagulation, and the circumstances romote or retard it.

lly, the physical analysis of the blood, and the characters of tituents.

thly, the chemical analysis of the blood.

I. *Of the Quantity of Blood in the Body.*—It is almost impossible to obtain sufficiently accurate data upon which to found a calculation of the total quantity of the blood which circulates in the vascular system. The various estimates which have been formed have been guesses, based on trials by bleeding animals to death, and comparing the weight of the blood drawn with that of the animal's body: also, on ascertaining, in various cases of hemorrhage, or of venesection, the quantity of blood which had been lost in a brief period, without destruction to life.

Harvey estimated the weight of the blood as one-twentieth of that of the body, and Haller at one-fifth. According to the former estimate, a man of one hundred and fifty pounds' weight would have only about seven and a half pounds of blood, whilst the latter would assign him thirty pounds.

Valentin devised an ingenious method of estimating the quantity of the blood. He first ascertains the amount of solid constituents in a certain quantity of blood, withdrawn by venesection; this is replaced by a certain quantity of distilled water, and then he ascertains the amount of solid constituents in a quantity of the now diluted blood equal to that which had been first withdrawn. From the data thus obtained he calculates the whole quantity of the fluid, which admits of such a change in its specific gravity, by the substitution of a certain quantity of distilled water for the quantity of the fluid itself previously withdrawn. The problem is, to determine the quantity of fluid of specific gravity B, which, on removing from it say six ounces, and replacing those six ounces by a certain quantity of distilled water, becomes reduced to the specific gravity β. Having by this method determined the quantity of the blood in dogs, he deduces the quantity of blood in the human body by comparing the weight of men with that of dogs. And thus he assigns about thirty-two pounds for a man between thirty and forty years of age, and twenty-eight pounds for the female.*

On the whole, we have no right to infer that the quantity of blood in the human body exceeds thirty pounds; and, for practical purposes, we shall do well to form a much lower estimate of it, and to learn from thence how important it is to avoid being prodigal in the removal of a fluid, so essential to the phenomena of life—and to beware of subjecting patients to those excessive losses of blood, which, experience teaches us, too often inflict upon the general nutrition of the body a shock so severe, that it is more or less seriously affected by it ever after.

II. *The Phenomena of Coagulation.*—We have already described the separation of the blood into serum and crassamentum. In this consists the phenomenon of coagulation. In a few minutes after blood has been allowed to rest in a vessel, its surface assumes the appearance of a jelly, on which, after a little more time, drops of serum appear to ooze out here and there; these drops multiply and coalesce, so as to cover the jelly-like surface with a layer of serum,

* Valentin, Physiol.

ncreases so much in quantity, as coagulation advances, that is at last found covered and more or less completely sur- l by serum.

rassamentum, or *clot*, is a solid mass, varying much in con- : sometimes soft and tremulous, like jelly; at other times d tough almost as leather. If a section of it be made, it found in most instances coloured throughout, but always eeply so at its lower half or third, the heavy red particles ing to the lowest part; that portion which is exposed to the ing always a scarlet tint. The surface of the clot is always concave; sometimes it is remarkably so, and exhibits the nce of a hollow cup, and on these occasions the upper layers clot generally consist of fibrine only, which is of a whitish or buff colour, with an intermixture of colourless corpuscles ed in its meshes. Hence blood which presents these appear- said to be "cupped and buffed." The phenomenon is due nore complete subsidence of the blood-particles as the clot is ormed, so that its upper layers are left quite free from colour- ter. The clot, when this state is present, is generally small, nd well contracted, and it floats in a large quantity of serum. period required for the completion of coagulation varies very it commences in about two minutes after the blood has been d in a vessel, and is rarely completed for half an hour after- but more frequently the clot is not perfectly formed in less e or two hours. After it has been formed, it will continue to t for many hours, and to press out the serum, which will thus e in quantity while the bulk of the clot undergoes diminution. ulation appears to take place more rapidly under the influ- a high temperature, 114° to 120°, according to Hewson; it favoured by spreading out the blood on a flat surface; and, certain limits, by an increase in the fluid parts of the blood. he other hand coagulation is retarded by the addition of alka- d some of their salts, as sulphate of soda, nitrate of soda, car- of soda, chloride of sodium, also carbonate of potass, nitrate ss, and nitrate of lime. A strong solution of any of these dded to fresh-drawn blood, will delay or stop its coagulation ng to the strength and quantity of the solution.

iors affirm that the blood will not coagulate in the bodies of killed by blows on the epigastrium, or after having been long , or by electricity or lightning. It will not coagulate after ia by carbonic acid, as in the following cases, recorded by ulliver: A man, ætat. thirty-five, and three children, were ted in a burning house, their bodies being untouched by the all of them the blood was fluid, forty-eight hours after death, heart and great vessels, and did not coagulate after its remo- of the body.

coagulation of the blood appears to be retarded by its contact ing surfaces. Thackrah's experiments showed that blood con- etween two ligatures in living vessels, remained fluid for a rable time, from five to sixty minutes; F. Simon affirms

that it will retain its fluidity for three hours; and experiments of the same kind by Hewson, lead to the conclusion that the coagulation is retarded under similar circumstances. Fluids withdrawn from serous cavities, as in ascites or hydrocele, often exhibit a coagulum of considerable size, which does not form till some minutes after their removal, showing that the fibrine must have been prevented from coagulating so long as it remained in the living cavity.

The addition of bile retards or prevents coagulation, probably by the mechanical obstacle which it affords to the cohesion of the particles of fibrine. According to John Hunter, the addition of a solution of opium to the blood retards its coagulation.

It is needless to waste time in inquiring into the cause of coagulation. That the phenomenon belongs only to one of the constituents of the blood is proved, unequivocally, by the fact that if that material, the fibrine, be removed by whipping blood with a bunch of twigs, as it flows from a vein, coagulation will not take place in the fluid which remains. The fibrine has accumulated in a coagulated state round the twigs, and the fluid received into the vessel consists only of serum and red particles. The coagulation of the fibrine of the blood is one of those ultimate facts in physiology which we must be content to observe and to describe, but of the cause of which we are likely to remain ignorant.

The *buffing* and *cupping* of the blood has long attracted the notice of observers, and is regarded by many practical men as an indication of a state of inflammation in some part of the body at the time of the abstraction of the blood. The immediate cause of this phenomenon is explained with the highest probability, as follows, by Dr. Babington:—

"The blood, consisting of liquor sanguinis and insoluble red particles, preserves its fluidity long enough to permit the red particles, which are of greater specific gravity, to subside through it. At length, the liquor sanguinis separates by a general coagulation into two parts, and this phenomenon takes place uniformly throughout the liquor. That part of it through which the red particles had time to fall, furnishes a pure fibrine or buffed crust, while that portion into which the red particles had descended furnishes the coloured clot." The following experiment, made by the same ingenious observer, illustrates the truth of the explanation given by him. "Take two similar tall jars or phials, each capable of holding about four or five ounces, and let one of them be half-filled with olive oil; draw the blood of a healthy subject into each. That which flows through the oil will be found to have a layer of liquor sanguinis on its surface, which will form a buffed crust, while there will be none upon that which is received in equal quantity, and in other respects under the same circumstances, into the empty jar."*

According to the observations of Nasse, and of Mr. Wharton Jones, the red particles of blood which is disposed to become buffed

* Med.-Chir. Trans., and Cyclop. Anat., art Blood

and cupped, exhibit a remarkable tendency to cohere in the form of rolls, like piles of coin, and this probably facilitates their precipitation to the lowest part of the coagulating mass.

The circumstances which favour the formation of the buffy coat may be any or all of the following: 1. Slowness of coagulation; 2. Increased weight of red corpuscles; 3. Diminished specific gravity of serum, which obviously would have a corresponding effect to the preceding; 4. A great diminution in the proportionate quantity of the red corpuscles, or an increase in that of fibrine, and of colourless corpuscles. The occurrence of the cupped and buffed blood, after great hemorrhage, or in cases of anæmia, is very probably in a great degree due to the disproportion between the red particles and the fibrine.

Although the phenomenon of cupping and buffing frequently occurs in that state which is called inflammatory, it is not so exclusively confined to it as to justify practitioners in regarding it, as is so often done, as a proof of the existence of inflammation, sufficient of itself to warrant or call for further depletory measures.

III. *The Physical Analysis of the Blood.*—By physical analysis we find in the blood the following parts; viz. the serum; the fibrine held in solution in the serum prior to coagulation; the red corpuscles and the colourless corpuscles, both of which float in the liquor sanguinis.

The *serum* is a straw-coloured fluid, of sp. gr. 1025 to 1030.—When heated to 165° it becomes nearly solid, proving that it holds in solution a very large quantity of albumen, as much as seven or eight parts per cent. In twelve ounces of serum there would, therefore, be nearly one ounce of albumen, equal to the white of one egg. But this is not the only ingredient which we find dissolved in the serum. It is an alkaline fluid, and its alkalinity is chiefly due to the presence of free soda, and of carbonate of soda. Besides these it contains chloride of sodium, phosphate of lime and of magnesia, and probably lactate of soda.

The serum also contains a small quantity of fatty matter in which can be detected the crystallizable as well as the oily portion. In health, the proportion of this does not exceed half a part in 1000 parts, so that a pint of serum will contain about five grains of fatty matter; but in some cases it exists in so large a proportion as to render the serum milky. This occurs not only in certain forms of disease, but likewise, according to Drs. Buchanan and R. D. Thomson,* very shortly after the ingestion of food of an oily or amylaceous nature.

Whatever other elements may exist in the blood, as serving to furnish materials for the various secretions, are held in suspension or solution by the water of the serum. Thus, urea is sometimes found in it, and the recent observation of Bernard, referred to at p. 604, shows that it constantly contains sugar; when the liver acts imperfectly, some of the elements of bile are found in it.

* Med. Gaz. vol. xxxvi. p. 972.

It is as yet uncertain whether the existence of even minute quantities of some of these substances in the blood, such as urea and the biliary matters, is consistent with health. It is not improbable that they may be constantly being developed by the chemical changes which are unceasingly going on in that fluid, but that they become attracted from it as quickly as they are formed in it, and do not accumulate in it in any quantity which admits of being easily detected. According to Dr. Thomson, sugar may be always easily detected in the blood, shortly after a meal containing starch.*

The Fibrine.—We have already explained the manner in which fibrine may be obtained from the blood. One thousand parts of healthy blood contain two or three of fibrine. A pint of blood will therefore yield about twenty-nine grains of fibrine, adopting the highest estimate.

Pure fibrine, or, to speak more exactly, fibrine separated from the *red* corpuscles, for it cannot be completely separated from the colourless corpuscles, has a remarkable tendency to assume the fibrous form. A drop of the colourless liquor sanguinis, which is found on the surface of blood, about to form a buffy coat, exhibits, when coagulated, an intricate interlacement of minute fibres.—Here and there a colorless cell is entangled in it, appearing as a centre, whence pass numerous radiations of minute fibres. Dr. W. Addison, who believes that the fibrine is contained within the colourless corpuscles, considers the bursting of a large number of them, and the consequent liberation of their inclosed fibrine, as the first step in the process of coagulation, which explains the entanglement of them in the fibrillating fibrine. The process may be best seen, as this excellent observer recommends, by examining a drop of the colourless liquor sanguinis from blood, about to form a buffy coat, and allowed to coagulate upon a slip of glass.†

The Red Corpuscles.—It is to the multitude of coloured particles which float in the liquor sanguinis, under the name of "the red corpuscles," that the blood owes its colour. To examine these, it is only necessary to place a drop of blood in the field of the microscope, taking care to dilute it with a fluid, similar or nearly so in specific gravity to the serum; a solution of sugar or of salt in water, answers this purpose completely. So numerous and so crowded together are the corpuscles in a drop of blood, that it would be difficult to obtain a complete view of any one of them without this precaution.

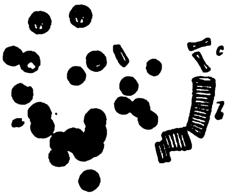
In the human blood, the coloured corpuscle is a circular double concave lens; from being concave on each surface, its margin is thick and rounded, and its thickness is less in its centre than at any other part (Fig. 173). Its size varies considerably; in the same drop of blood there are corpuscles of all sizes within a range of from $\frac{1}{3000}$ to $\frac{1}{2500}$ of an inch in diameter, the average being from the $\frac{1}{3500}$ to $\frac{1}{3200}$. With a good microscope, and a magnifying power of 200 diameters, the characters of the blood-corpuscles may be most clearly seen, and when the instrument is perfectly adjusted,

* *Loc. cit.*

† Dr. W. Addison's second series of Exp. Researches, 1843.

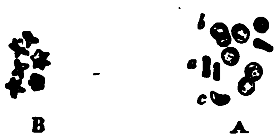
e double concave surface may be unequivocally demonstrated. If e corpuscles are floated in water, they become biconvex; if in a id denser than serum, as in a strong saline or saccharine solution, ey shrink, put on a shrivelled aspect, and become granulated on

Fig. 173.



ed corpuscles from human blood. *a*. Viewed the surface. *c*. Viewed in profile. *b*. An regation of the corpuscles in a roll.—Magni- 400 diameters.

Fig. 174.



Red corpuscles of the ox, magnified 400 diameters. A. In their natural state. *a*. Profile view. *b*. Viewed on the surface. *c*. A corpuscle altered in shape. B. Corpuscles altered by a menstruum of high density.

eir surface (Fig. 174, B); this shrivelled appearance may again be t rid of by diluting the menstruum and reducing its specific avity to the lowest point.

It has been affirmed, by Mulder and others, that the blood-corscles of venous blood are biconvex—those of arterial being biconve—and they attribute the difference of colour of these two kinds blood to the different mode in which the light is reflected from e concave and the convex surfaces of their respective corpuscles. ith reference to this doctrine, we have only to state that we have refully examined two portions of the same blood after they had en agitated in oxygen and carbonic acid gas, and thus been renred respectively scarlet and purple, but that we have failed to tect any well-marked difference in shape between the bloodrpuscles of the two specimens.

The blood-particles have a remarkable tendency to aggregate in ls like pieces of coin (Fig. 173, *b*): this tendency, as has been eady remarked, is said by some to be greatly increased in blood ich forms a buffy coat in its coagulation.

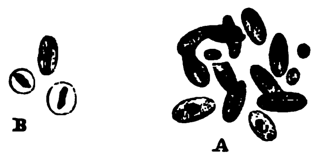
The red blood-corpuscle of Mammals resembles in shape and structure that of n (Fig. 174): there is much diversity of size in the various orders; it is smallest the ruminants, and the smallest known is that of the Napu musk-deer, which is erted by Mr. Gulliver not to exceed 1-12,000 of an inch in diameter. The corpuscles the goat are very small, 1-6300—1-7045 of an inch in diameter. The largest corscles in Mammalia are found in the elephant; they measure, according to Gulliver, 745 of an inch in diameter. The Camelidæ offer a remarkable exception to the ular form of the blood-corpuscle of Mammalia. In these animals it is oval, as t pointed out by Mr. Gulliver, with a long diameter of from 1-3100 to 1-3550 of inch, and a short diameter of 1-5800 to 1-6444; in all other respects, however, these puscles agree with those of other mammals.

n Birds, the corpuscles are oval in shape; they have a very distinct nucleus, ich is much smaller than the corpuscle itself. The long diameter of the blood-corcle of Birds ranges between 1-1500 and 1-2000 of an inch, and the short diameter n 1-3000 to 1-4000 of an inch. (Figs. 175, 181, 183.)

n Reptiles, the red corpuscles are of an oval shape, with a distinct and large leus (Fig. 176). The long diameter of the corpuscle has a range of from 1-420 to

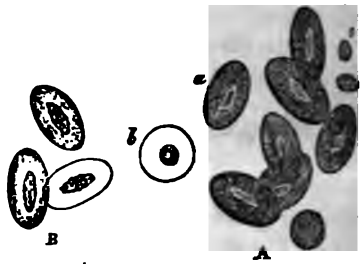
1-1400 of an inch, the short diameter ranging between 1-760 to 1-2600 of an inch.—Among these are to be found the largest known blood-corpuscles, as those of the proteus and of the syren.

Fig. 175.



Red corpuscles of pigeon's blood, magnified 400 diameters. A. Red particles unaltered, with two or three colourless particles. B. Treated with acetic acid, which develops the cell-wall and nucleus more clearly.

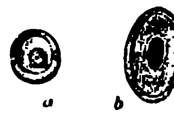
Fig. 176.



Blood-corpuscles of the common frog. Magnified 400 diameters. A. In serum. *a*. Fully developed corpuscle. *b*. Nucleus with pale cell-wall and clear contents. *c*. Colourless corpuscle. B. Treated with acetic acid.

In Fishes, the red corpuscle is oval in most of the genera, and possesses a distinct nucleus (Fig. 177, *b*). In the lowest cartilaginous fishes, as the lamprey and the myxine, however, it returns to the circular and biconcave form of the Mammalian red corpuscle (Fig. 177, *a*). This remarkable fact was first pointed out by Professor R. Wagner. Mr. Wharton Jones has shown that it contains a nucleus, which cannot be detected in the red corpuscles of Mammalia.

Fig. 177.



Red corpuscle of fishes. *a*. Lamprey. *b*. Skate.—After Wharton Jones.

Fig. 178.

Blood-corpuscles of the crab. A. Granule cells. B. Nucleated cells.—After Wharton Jones.

In the Invertebrate classes, corpuscles exist which are in close analogy with those of the Vertebrata, but differ from them in several particulars (Fig. 178). They are nucleated cells, some of which contain within them numerous granules which conceal the nucleus; some of these corpuscles, according to Mr. Wharton Jones, are, upon their first removal from the body, of an elongated oval form, and others spindle-shaped. Their size does not exceed 1-2000 of an inch in their long diameter, and 1-3000 in the short. In most of the classes the particles do not exhibit any indications of colour, although they contain some of the ingredients of hematine: in a few, however, slight traces of colour are present.*

Of the Structure of the Red Corpuscle.—The structure of the red corpuscle of most of the Vertebrata may be readily demonstrated in the blood of Reptilia—that of the frog, for instance.—It is distinctly a nucleated cell—consisting of a delicate cell membrane, within which is a granular nucleus, which may be rendered more distinctly granular by acetic acid (Fig. 176, B). The nucleus is globular and much smaller than the cell, and the interval between

* Mr. Wharton Jones's papers in the *Phil. Trans.* for 1846, "On the blood-corpuscle considered in its different phases of development in the animal series," contain an account of a careful examination of these particles, and may be referred to with advantage by all who are engaged in the study of this most interesting subject.

the inner surface of the latter and the outer surface of the former is filled by fluid which holds the colouring matter in solution. Corpuscles of this kind floated in pure water become distended by the endosmosis of it, burst, and give exit to their nuclei, while the shreds of the cell-membrane are scattered in the fluid.

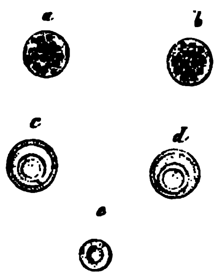
It cannot be shown satisfactorily that the biconcave circular corpuscle of human blood and of that of mammalia is of the same structure as this, because it cannot be demonstrated to consist of cell and nucleus. If it be as the blood-corpuscles of birds, reptiles, and fishes undoubtedly are, a nucleated cell, the obscurity of its nucleus is probably due to one of two causes; either it is so large as accurately to fill the cell, leaving no space between the outer surface of the one and the inner surface of the other, or it is so extremely minute as completely to elude our means of observation.

Mr. Wharton Jones supposes that the mammalian red corpuscle is a nucleus, the cell of which had existed only in the earlier stages of development. Kolliker, on the other hand, affirms that the nucleus disappears while the cell-wall is persistent. All that microscopic examination with the highest powers and the best instruments shows respecting the structure of this corpuscle is that it consists of a delicate membrane, inclosing a semifluid material, impregnated with the proper colouring matter of the blood; and that this structure may truly be assigned to it is amply proved by the change of form which it undergoes by the endosmosis of pure water, which will cause it to burst and evacuate its contents, consisting of nothing more than some minute granules, none of which can be compared to a nucleus. So far as microscopic analysis would enable us to decide this question, we should be disposed to declare in favor of Mr. Jones's view; but it seems greatly opposed by two facts; first, that in the corpuscle of the lower vertebrata, the colouring matter is contained between the nucleus and the cell-wall, whereas in the mammalian corpuscle it would be contained in the nucleus; and, secondly, that this peculiarity of structure is limited to one class of vertebrate animals. It receives support, however, from observing the several steps of the development, for the corpuscle exhibits a stage in which a nucleus is visible (the stage of coloured nucleated cell,) (Fig. 179, *d*,) and this nucleus, in the very large corpuscle of the elephant, and likewise in the very small corpuscle of the goat, exhibits a strict correspondence in size with the perfectly formed blood-corpuscle. But here, again, we notice the difficulty above referred to, that in this stage of nucleated cell, the colour is found between the cell and the nucleus. It seems to us that further research is required, in order to determine the exact homology of the mammalian red corpuscle.

The Colourless Corpuscles.—These particles are found in all kinds of blood. They are spherical bodies, destitute of colour; their structure is that of nucleated cells, the cell-membrane being extremely delicate; both the cell-membrane and the nucleus and nucleolus are rendered distinct by the action of dilute acetic acid, which dissolves some granules which are contained in the cell.—These granules are external to the nucleus. When they are

numerous and large the nucleus is concealed by them. Corpuscles of this kind, denominated *granule-cells* by Mr. W. Jones (Fig. 179, *a*, *b*), are viewed by him as constituting an earlier stage than those in which the nucleus and nucleolus are distinct, which he calls *nucleated cells* (Fig. 179, *c*, *d*). In size, the colourless corpuscles slightly surpass the red corpuscles in mammalia, but not in the other vertebrata. They are essentially the same as the nucleated particles found in lymph and in chyle.—In examining the capillary circulation in the transparent parts of some animals, as the web of the frog's foot, they may be seen sparingly at the margin of the current of red corpuscles, either stationary and adherent to the wall of the blood-vessels, or slowly moving forward in the layer of liquor sanguinis which is in contact with the wall, and which is thus shown to be comparatively motionless.

Fig. 179.



Phases of the human blood-corpuscle (after Wharton Jones). *a* and *b*. Granule-cells in the coarsely and finely granular state. *c* and *d*. Nucleated cells, *c* without colour, *d* with colour. *e*. Free cellæform nucleus or perfect red corpuscle.

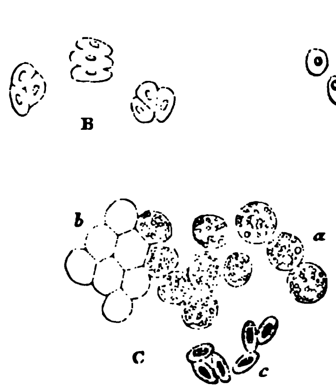
The colourless corpuscles are much fewer in number than the coloured; it is said that they exist in the proportion of one colourless to fifty coloured, but that in inflammatory states of the blood, the former are much more numerous, being as one in twelve. After great loss of blood, the proportion of the colourless corpuscles is considerably increased.

A very important inquiry is to determine—1. The histological relation of these particles to each other; and, 2. The part which they take respectively in the vital phenomena of the blood.

With regard to the first point, physiologists are divided in opinion as to whether they may be regarded as distinct and independent particles, performing each their special functions, or whether the one, namely, the colourless corpuscle, may be viewed as an early or embryo condition of the red corpuscle.

The weight of argument seems to favour the conclusion that the colourless corpuscles are to be regarded as an early stage of the coloured

Fig. 180.



Corpuscles from the bloodvena of the cava hepatica of the embryo chick on the twentieth day of incubation. A. Red blood-corpuscles altered by water. B. Blood-corpuscles coherent and modified in shape by cohesion. C. *a*. Large spherical cells containing highly refracting granules (fatty). *b*. The same represented only in outline, to show their shape. *c*. Fully formed red corpuscles.—Magnified 200 diameters.

corpuscles, which are in the adult or perfect state. In the earliest periods of fœtal life, the blood-corpuscles, as is shown by the researches of Vogt, Kölliker, and Cramer, originate, in the same way as the elements of the tissues, from nucleated cells, which are the same in point of constitution as the colourless corpuscles; with this exception, that they contain between the nucleus and the cell a considerable number of granules, which are largest at the earliest periods of embryonic life. At later periods similar nucleated cells are generated in the liver, as first pointed out by Weber, and in the mesenteric and lymphatic glands, and from these sources supplied to the blood. In this fluid they undergo a transformation into the completely formed blood-corpuscles, by the removal of the granules, the increased development of the nucleus, and the generation of colouring matter, excepting in the mammiferous corpuscle, whose ultimate change seems to consist in the complete absorption of the nucleus, according to Kölliker, or the removal of the wall of the cell, according to Wharton Jones.

Fig. 181.

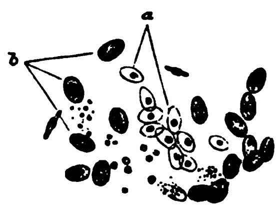
Granules, granule-cells, and red blood-corpuscles from the embryo chick at the twentieth day of incubation. *a a.* Granules, some being enveloped by a faint cell-wall, and granule-cells with coarse granules. *b b.* Red blood-corpuscles.—Magnified 200 diameters.

Now, as there can be no doubt that, in the adult, the lymphatic and chyliferous systems afford a source for the constant development of particles identical with the colourless corpuscles, and as such corpuscles are always found in considerable proportion in the blood (being more numerous under circumstances unfavourable to normal changes, as in inflammations), it seems very reasonable to infer that similar transformations of colourless into coloured particles are going on in the adult as in the embryo, and that the lymphatic and lacteal systems must be at least one, and that a fertile source, from which red corpuscles are being continually supplied to the blood.

Fig. 182.

a. Granules of which the cell-wall is not visible. *b.* Granule-cells and red corpuscles.—Magnified 200 diameters.

Fig. 183.



Nucleated cell (*a*), red corpuscles (*b*), and granules from the chick on the 20th day of incubation.—Magnified 200 diameters.

If, however, we reject this view of the relation of the colourless to the coloured corpuscles, then we must regard them as independent particles, each having its special function; and it devolves upon the advocates of this view to suggest the office, and to explain the mode of origin and decay of each.

Function of the Red Corpuscles.—It is clear that the red corpuscles must perform some very important office in the life of the blood, because of their great numbers, their constancy, and the serious consequences to the general nutrition and the vital actions of the body, which ensue upon any considerable diminution in the quantity of them. But we have no definite knowledge on this subject, and all that can be suggested is, as yet, of a speculative and hypothetical nature.

Liebig adopted the highly ingenious notion that the red corpuscles are carriers of oxygen, and that by their colouring matter they are peculiarly adapted for attracting that principle. The property of attracting oxygen is due to the iron, which forms six per cent. of the hematine contained in the red corpuscle. In venous blood, according to Liebig, the iron is in the state of *carbonate of the protoxide* of iron; this, as the blood passes through the capillaries of the lungs, or becomes otherwise exposed to the action of the air, is by the absorption of oxygen converted into *the hydrated peroxide* of iron, the state in which that metal exists in arterial blood. And at the same time it gives off "for every volume of oxygen necessary for the change from protoxide to peroxide, four volumes of carbonic acid." As the arterial blood passes through the capillaries of the system, the peroxide of iron yields oxygen to certain constituents of the body, which is employed in producing the change of matter, and in oxidizing newly-formed substances in the blood, while in their return towards the heart, the red particles which had lost their oxygen "combine with carbonic acid, producing venous blood; and when they reach the lungs an exchange takes place between this carbonic acid and the oxygen of the atmosphere."

This doctrine of Liebig assigns the use of the colouring matter, or of the contents of the blood-corpuscle, rather than of the corpuscle itself; it is, indeed, highly reasonable to suppose that the hematine has an important connection with the attraction of oxygen into the system, or to speak more generally, with the changes which take place in the blood in respiration. The difference of colour, being the prominent feature of distinction between arterial and venous blood, is strongly indicative of this; and also the fact now demonstrated by Mr. Wharton Jones, that the blood of the invertebrata contains a certain degree of colour, or at any rate, even where no colour can be distinguished, according to Professor Graham's analysis, "a sensible quantity of iron, perhaps as much as red corpuscles."

Liebig, however, does not explain why the hematine is invariably contained in a multitude of nucleated cells. The consideration of this point seems to us to afford the clue to determine the real function of the red particles.

The true office of the red blood-corpuscles would, probably, be most correctly described as that of forming or secreting *the hematine*, which in the greatest part of the animal kingdom is *coloured*, but which even, though *colourless*, appears to contain iron. These particles are floating gland-cells, as Henle suggested some years ago; they are in all essential points of structure like the secreting cells of true glands, and there is no reason why, free and floating in a liquid like the liquor sanguinis, they may not exercise upon materials dissolved in that fluid an influence analogous to that exercised by the elementary particles of the liver, or the kidney, or the pancreas upon the blood. The matter secreted by the blood-cells is the hematine, which term we would here use to signify not merely the colouring matter, but the entire contents of the blood-corpuscle, of which iron is an important if not an essential ingredient, and which is coloured in the vertebrata and in some of the invertebrata. It is this hematine which plays an important part in the attraction of oxygen, and which by its colouring matter also exercises some important influence on the whole economy; for there seems no other source from whence can be derived all that pigment which is diffused throughout various textures, such as muscle, the nervous centres, the skin and its appendages, the eye, &c., but that which is formed in such great quantity in the blood.

Office of the Colourless Corpuscles.—If these particles do not constitute an early stage of development of the coloured corpuscles, it is clear that they must be viewed as performing some special function in the blood, independently of the latter. R. Wagner viewed them as identical with chyle and lymph corpuscles, and assuming that in the invertebrata no coloured particles existed, he regarded the blood in such animals as identical with chyle or lymph; as, in fact, the latter fluid not yet elaborated into blood.—In the blood of vertebrata, therefore, he would view these particles as chyle or lymph globules not yet transformed into blood particles.

But Dr. Carpenter has put forward a more elaborate hypothesis respecting the office of the white corpuscles. This able physiologist regards these particles as the agents in the development of fibrine in the blood, or in the conversion of albumen or other materials of that fluid into that "plastic" compound. This substance certainly first appears in the chyle and lymph, where these particles are found in great numbers floating in an albuminous fluid. Nor does it appear in the chyle until after that fluid has passed through the mesenteric glands, which furnish these particles in large numbers.

Dr. Carpenter regards the appearance of these colourless corpuscles or cells in the blood as a phenomenon in close analogy with the development of cells in the albumen of the seed in the vegetable kingdom, and in the yolk of the eggs of oviparous animals; and he supposes that the office of these cells is to convert crude alimentary materials into proximate principles, which again, through the agency of cells, may be converted into, or may afford the materials for the

peculiar compounds which form the characteristic ingredients of the secretions, or may pass into organized tissue.*

Of the Development and Decay of the Blood-Corpuscles.—It seems to us that the view which Mr. Wharton Jones takes respecting the development of the blood-corpuscles, already described at pp. 637, 638, affords the most simple and correct explanation of the origin and development of these particles. According to it, the lacteal and lymphatic systems may be regarded as the source whence fresh supplies of blood-corpuscles are being continually furnished to the blood at all periods of life. In the early embryo, as well as in the adult, the process of the formation of the blood-corpuscle would be the same; that is, the development of a nucleated cell, which undergoes transformation into the coloured particle; the steps of the process being successively *granule cell*, *nucleated cell*, and *coloured particle* (Fig. 179). This view would lead us to regard the system of lymphatic and mesenteric glands as the seat of an unceasing generation of new particles, which undergo their later stages of transformation in the blood. And it is well worthy the attention of pathologists, as affording an explanation of the great influence which (as we learn from experience) this extensive system of glandular bodies exercises upon general nutrition.

Prior to the formation of this glandular system and the development of the lymph and chyle corpuscles, the blood-particles are derived as nucleated cells from the cells of the germinal membrane, but they undergo essentially the same changes as in the more advanced periods of life. In mammalian embryos they are described "as of large size, spherical or oval, pellucid and colourless, nucleated, and full of minute granules." Mr. Paget, whose description we follow, confirms the observation made by Kölliker, Fahrner, and others, of the occasional occurrence of "a process of multiplication by bi-partition of the nucleus, each of which, either by appropriating half the cell, or by developing a cell around itself, becomes the central nucleus of a new cell, differing from the parent cell from which it escapes in little except in being smaller and more generally circular."†

Of the manner in which the blood-corpuscles decay we really know nothing—no more than of the mode of decay of the elements of the tissues. The notion held for a time, by some physiologists, that the existing particles gave birth to new ones by a gemmiparous or fissiparous generation, has no foundation in careful observation. And it is most probable that, as Mr. Paget remarks, "new corpuscles never appear to be produced from the germs of old ones; when a corpuscle is past its perfection, it degenerates and probably liquefies." "The changes of such degeneration," adds this excellent observer, "have not been clearly seen in mammalian corpuscles; but they are

* Dr. Carpenter's remarks on this subject deserve the attentive perusal and consideration of physiologists.—See *Principles of Human Physiology*, §§ 155-159, fourth Am. Ed.

† Kirkes's Handbook of Physiology, Am. Ed. p. 63, Fig. 12.

probably nearly similar to what occur in those of fish and reptiles; in which the old and degenerate corpuscles appear perfectly white and pellucid (not shaded or granular, like the lymph-corpuscles), smaller than they were, and in some instances cracked, or as if eroded. The nuclei appear to degenerate with the cells, but because of their darker and harder outlines, remain longer distinct, and often look like free nuclei, unless the dim cell-wall round them be carefully searched for. But in this process, no germ for a new corpuscle issues from the transient cell. Every new corpuscle forms itself in and from the materials of the lymph and chyle, and is perfected in the blood, and the blood is maintained by constant repetitions of this process."*

Kölliker has lately put forward the remarkable opinion that the spleen is the seat of a process of destruction or dissolution of the blood-corpuscles. We shall examine this view farther on, when we come to describe the structure of the spleen.†

IV. *The Chemical Analysis of the Blood.*—The blood is a fluid of the greatest complexity, as must be expected, if we regard it as containing the material for the nutrition of all the tissues, as well as for all the secretions. Thus, in addition to the water which forms four-fifths of it, and without which no transfer of materials could take place from it to other parts, it contains albumen for the albuminous tissues; fibrine for the fibrinous; salts which are found in the various secretions; colouring matter, which, more or less modified, is found in the nervous matter, the skin, the eye, the bile, the urine, the cerumen; and fatty matters identical with those which are found in fat.

The researches of the last few years, in which Lecanu, Andral and Gavarret, Rees, Becquerel and Rodier, Christison, Miller, and others have taken a conspicuous part, have determined, with a very near agreement, the relative proportions in which the various staminal principles exist in healthy blood.

The following method may be adopted for this kind of quantitative analysis.‡ Let the blood flow at four different periods and in equal quantities into two vessels; the first and third into the first vessel; the second and fourth into the second; the weight of each should be taken.

From one portion the fibrine may be separated by whipping, or by shaking up the blood in a bottle containing small pieces of lead; the residue will consist of the serum and red particles. The weight of this, deducted from that of the whole portion of blood, will give the weight of the fibrine.

The second portion may be set aside to coagulate spontaneously; when this process is completed, the crassamentum must be taken out, and, after the serum has completely drained away from it, it should be weighed. The weight of the fibrine, as obtained by the first experiment, being deducted from that of the entire clot, will give that

* *Loc. cit.* p. 67. † Art. *Spleen*, Cyclop. Anat. and Phys.

‡ For a more elaborate and exact method of analysis, see Mr. J. E. Bowman's "Handbook of Medical Chemistry," Am. Ed. p. 160.

of the coloured corpuscles. The amount of albumen may be obtained by precipitating it from the serum, and weighing it after filtration.

The general results of this method of analysis may be thus stated roughly. In one hundred parts of blood, about seventy-eight parts are fluid and twenty-two parts solid material; and of the last, the albumen constitutes rather less than seven parts, the fibrine one-fourth of a part, and the red particles rather more than fourteen parts.

The following table gives a summary of the analysis of the blood of healthy individuals of both sexes, by Becquerel and Rodier, who are among the most recent analysts.

Composition of one thousand parts of blood *in men*, derived from eleven analyses.

	Mean.	Maximum.	Minimum.
Water	779	760	800
Red particles	141.1	152	131
Albumen	69.4	73	62
Fibrine	2.2	3.5	1.5
Extractive matters and free salts	6.8	8	5
Fatty matters	1.6	3.255	1

Composition of one thousand parts of blood *in women*, derived from eight analyses.

	Mean.	Maximum.	Minimum.
Water	791.1	773	813
Red particles	127.2	137.5	113
Albumen	70.5	75.5	65
Fibrine	2.2	2.5	1.8
Extractive matters and free salts	7.4	8.5	6.2
Fatty matters	1.62	2.86	1

Composition of the Red Particles, and of the Hematine.—The large proportion which the coloured particles form of the solids of the blood, entitles them to the most attentive consideration of physiologists; they are more than fifty times the quantity of the fibrine, and nearly double as much as the albumen.

The red corpuscles consist, according to most chemists, of two elementary substances, globuline and hematine; the former is nearly allied to if not identical with albumen, and forms the solid part of the blood-corpuscle, its cell-wall, and nucleus, when it exists; the latter is the colouring material, or blood-pigment.

The following process is recommended by Figuier for the separation of the hematine from the globuline.

Defibrinated blood should be mixed with at least four times its bulk of a saturated solution of sulphate of soda; the mixture must then be thrown on a filter; the fluid and some corpuscles pass through, leaving the mass of coloured particles on the filter. This must next be boiled in alcohol, slightly acidulated with sulphuric acid: the hematine will be thus dissolved, the colourless globuline, in combination with some of the sulphuric acid, remaining undissolved.

The next step in this process is, to add to the hot solution of hematine enough carbonate of ammonia to remove the sulphuric acid; the fluid must then be filtered, to remove the sulphate of ammonia thus formed, and the liquor must be exposed for evapora-

when, by this means, it is reduced one-twelfth of its bulk, it ; found to deposit hematine as a dark or black powder.

s hematine is insoluble in water, alcohol, or ether, unless with some alkali, which renders it readily soluble; when l, it yields a considerable quantity of iron.

lder's ultimate analysis gives the following as its composi-

Carbon	66.84
Hydrogen	5.37
Nitrogen	10.40
Oxygen	11.75
Iron	66.5

ch difference of opinion exists among chemists as to the state ch iron exists in the blood. We have already referred to the n of Liebig, who affirms that in venous blood it is in the of protoxide, while in arterial blood it is in that of peroxide; at the change of colour, from the dark red of the former to ight scarlet of the latter, is due to the conversion of the pro- of iron into peroxide by the absorption of fresh oxygen at ngs. Mulder supposes that it exists in the metallic state as ple ingredient, as essential to the colour as its oxygen, its gen, its carbon, or its nitrogen. Scherer's experience, how- would go to show that iron is not essential to the colour of ood. He treated the red particles with sulphuric acid, so as to e their iron, and found that their colour still remained.— ; he infers that iron is not essential to the *colour.*

; value of the administration of iron in the treatment of cases emia after loss of blood, is well known and highly appreciated actitioners; it remains to be determined in what way it con- es so powerfully, as it unquestionably does, to the restoration ; blood to its normal state. The fact that it does exercise a ful influence evidently indicates its importance as an ingre- in the hematine. And it may be remarked that iron, even ; essential to its *colour*, may nevertheless be an essential in- nt of a normal hematine.

ference of Arterial and Venous Blood.—The prominent differ- between blood drawn from the arteries and that from the is to be found in the bright scarlet colour of the former, and ark red, almost black, of the latter. To which may be added difference of temperature, that of arterial being one or two es higher than venous; perhaps also some difference as to den- but upon this point observers are very far from being agreed; lso as to the proportions of solid constituents; but on this sub- ikewise, the reports of analyists are contradictory and highly isfactory.

e blood of the vena porta is said by F. Simon to coagulate slowly and less perfectly than ordinary venous blood; it con- less fibrine and much more fat.

luence of Venesection and of Disease upon the Blood.—The nce of venesection and of some morbid states upon the rela-

tive quantities of these constituents of the blood deserves to be well impressed upon practitioners.

Venesection, or the loss of blood by any means, reduces the amount of the red particles chiefly, and the more so in proportion to its frequency; the serum is diminished in density, and the quantity of the albumen and the fat is slightly reduced; that of fibrine is not affected, nor are the extractive salts.

The following cases from Dr. Christison illustrate the influence of venesection upon the blood.

The first is that of a middle-aged woman, who had been previously repeatedly bled for palpitations of the heart. The analysis of her blood gave the following result:—

Fibrine . . .	2
Solids of serum . . .	76
Red particles . . .	57
Water . . .	863

In the second case there had been frequent bleedings after rheumatism:—

Fibrine . . .	4
Solids of serum . . .	93
Red particles . . .	57
Water . . .	844

This latter case shows how impotent is venesection, even when carried to a great extent, over the reduction of fibrine, the material that forms those new deposits of organizable matter or plastic lymph, which in inflammations of internal organs, such as the lungs and heart, so much interfere with their normal action.

The following experiment, also, illustrates the effect of venesection upon the blood, first, when the animal was well fed at the time when the bleedings were being practised; and, secondly, when it was starved between the operations.

A large dog was fed upon two pounds of meat, and a quart of milk a day, and six ounces of blood were drawn on each of four successive days from his jugular vein. The blood was analyzed by our friend, Mr. Lionel Beale, Jun., who obtained the results shown in the following table:—

No. of Bleedings.	First.	Second.	Third.	Fourth.
Water . .	783.79	810.89	815.18	813.04
Fibrine . .	2.42	4.72	4.34	3.99
Solids of serum	70.94	70.85	69.92	76.01
Blood-corpuscles	142.85	113.54	110.58	106.95
	1000.00	1000.00	1000.02	1000.00
Density of serum	1025.8	1024.8	1023.5	1023.6

Here, notwithstanding the liberal allowance of food, the red particles suffered a considerable diminution.

The dog was now allowed to recover, and was well fed for three weeks, and at the end of that time his blood was analyzed: he was then starved for four days, being allowed nothing but water, and on each of these four days was bled. The following table gives the result of these analyses.

No. of Bleedings.	First.	Second.	Third.	Fourth.	Fifth.
Water . .	802.71	804.40	805.44	838.30	849.84
Fibrine . .	2.28	1.91	3.95	5.26	5.13
Solids of serum	74.13	72.61	71.46	68.46	71.62
Blood-corpuscles	120.88	121.08	119.15	87.98	74.21
	Dog fed.	Dog starved.			

In the latter experiments we notice a diminution of the red par-les to an extent even more marked than in the former; and it ıy also be observed that even after a lapse of three weeks, with od feeding, the red particles had not recovered their original ıount.

With reference to the estimate of the quantity of fibrine, it is ght to observe, that, both in these and all other analyses, it is ıble to an important source of fallacy, which arises from the im-ssibility of forming a separate estimate of the quantity of the lourless corpuscles which adhere to the fibrine, and must necessarily crease its apparent quantity.

The modifications which disease produces in the relative quanti-s of the blood-constituents, are chiefly referable to an increase al or apparent) in the quantity of fibrine, or a diminution of that ment, or of the blood-corpuscles; or, lastly, to such an alteration the quality of the fibrine (its quantity being unaltered) that its agulating power is materially interfered with.

In diseases of an inflammatory type, in which there is active 'er of a sthenic character, with proneness to effusion of plastic nph, or to the formation of thick laudable pus, fibrine is said to increased in quantity to as much as five or six parts in one thou-ıd of blood; it is also said that there is an increase in the colour-s corpuscles, and at first a slight increase in the coloured corpuscles, ıugh these latter afterwards undergo a diminution, which is the more rked in proportion to the extent of depletory measures employed. no diseases are these changes in the blood more conspicuous than rheumatic fever, pneumonia, and pleurisy. The cupping and fing of the blood is very marked, and the most exquisite examples that interesting phenomenon may be obtained from patients ouring under these maladies. Sufficient allowance, however, does t seem to have been made by observers generally for the ex-ıt to which the apparent increase of fibrine may be explained by ı increase of the colourless corpuscles.*

* Zimmerman, and more recently Mr. John Simon, in his valuable lectures on hology (*Lancet*, 1850, and since republished in 8vo.), have advocated the doctrine, el indeed, but most worthy of attention, that the fibrine of the blood must be re-ded not as an ingredient prepared for the nourishment of certain tissues, and ly to be appropriated by them, but as "among those elements which have arisen in blood from its own decay, or have reverted to it from the waste of the tissues." Simon has been led to adopt this opinion chiefly from observing the unaltered even increased quantity of the fibrine under bleeding, starvation, anæmia, and r states of exhaustion and increased waste, and also from the fact that in these ects the fibrine is in direct contrast with the red particles which are rapidly aced by these means. This view is also favoured by the fact noticed by Andral and arret, that an improvement in the breed of an animal tended always (cæteris pari-) to increase the proportion of the red particles, *but to diminish that of the fibrine.* ı small quantity of fibrine in fœtal blood, the absence of fibrine from the egg, the me, and the smaller quantity of it in the blood of carnivora (which feed on it)

Diminution of the quantity of fibrine, accompanied with a decrease in the red particles, occurs chiefly in fevers arising from the presence of a poison in the system. None show these changes more than those fevers which are caused by the paludal poison—namely, intermittent fevers. In rheumatic fever, and in acute general gout, there is a remarkable tendency to the diminution of the coloring matter of the blood, even when these diseases have been treated in the mildest manner. It would seem as if the materies morbi acted as a blight upon the red corpuscles, and prevented their development in the normal proportions.

In some cases—especially those connected with enlarged liver and spleen—the diminution in the coloured particles is accompanied by a remarkable increase in the number of the colourless particles.—Some cases of this condition of blood have lately been collected by Professor J. H. Bennett, who proposes for it the name *Leucocythemia* (λευκος, *white; κυτος, a cell; αἱμα, blood*).*

The fatty matters of the blood are sometimes increased in quantity apparently from non-elimination. Under these circumstances the serum becomes quite milky, an appearance which is quite characteristic of this state of blood, and may be removed by ether. We have already alluded (p. 633) to the milkiness which follows the ingestion of fatty food, but which cannot be regarded as abnormal.

There is a condition of blood to which F. Simon has given the name *spanæmia* (σπανος, *poor*), and which is popularly called *poor blood*. This is characterized by changes in the *quality* rather than in the quantity of the blood-constituents, and especially, perhaps, in the quality of the fibrine. When the blood is in this state, hemorrhages are of frequent occurrence, owing probably to the imperfect manner in which the coats of the bloodvessels are nourished. Purpura and scurvy are well-known diseases, of which the prominent feature consists in this poorness of blood. In the former malady, we have found the blood-corpuscles shrivelled, and even disintegrated;† but it is difficult to determine whether this was due to a defect in their mode of generation and development, or to a diminished specific gravity of the serum favourable to its endosmose by them.

On the subject of the blood, reference is made to the works on Physiology already quoted; Hewson's works, by Gulliver (Sydm. Soc.); J. Hunter on the Blood, &c.; Mr. Gulliver's numerous and valuable observations in the Appendix to the English edition of Gerber's Anatomy, and in his notes to Hewson's works; Simon's Animal Chemistry, by Day (Sydem. Soc.); Wharton Jones, On the Blood-corpuscle considered in its different Phases of Development in the Animal Series, Phil Trans. 1846; Kölliker, über die Blut-Körperchen eines menschlichen Embryo und die Entwickelung der Blut-Körperchen bei Saugethieren; Nasse, über das Blut; Sharpey and Quain's Anatomy; Dr. Miller's article on Organic Analysis in the Cyclop. of Anat.; Andral, Essai d'Hématologie Pathologique; Becquerel and Rodier, Recherches sur la Composition du Sang, &c., 1844; Dr. Owen Rees on the Blood and Urine; Mr. J. E. Bowman's Practical Handbook of Medical Chemistry; Mr. John Simon's Lectures on General Pathology, 1850.

than in that of the herbivora, are additional facts adduced by Mr. Simon in support of this view.

* Monthly Journal of Med. Science, Edinb. Jan. 1851.

† See a case.

CHAPTER XXVIII.

THE CIRCULATION OF THE BLOOD.—THE SANGUIFEROUS SYSTEM.—ARTERIES.—VEINS.—CAPILLARIES.—THE HEART, IN THE LOWER ANIMALS, IN MAN.—PHENOMENA OF ITS ACTION.—COURSE OF THE CIRCULATION IN MAN.—FORCES BY WHICH THE CIRCULATION IS CARRIED ON IN THE ARTERIES, CAPILLARIES, AND VEINS.

It is difficult to comprehend how it escaped detection for so long a time that the complex fluid, the properties of which were considered in the last chapter, is perpetually in motion. Physiologists were not insensible of the importance of the blood to the general nutrition of the body; but of its relation to the elements of the various tissues, they seem to have formed no adequate idea.

The discovery of the circulation of the blood by our immortal Harvey, and first taught by him in 1619, was, perhaps, the most perfect physiological induction from well-ascertained anatomical facts ever made. A careful study of the anatomy of the veins and of their valves, and also of the heart and its valves, and the comparison of the possible relation which these mechanical contrivances in the one, might bear to those in the other, led to the inevitable inference that the fluid contained in these vessels and in the heart, not only moved, but also moved in a certain and uniform direction.

The agents of the circulation of the blood, are the heart and the bloodvessels; the latter being a series of tubes of various sizes and structure, and of various vital endowments; the former a sort of living forcing-pump in free communication with this system of tubes, which, by its unceasing action, keeps the blood in continual motion.

We shall first examine the structure and vital endowments of each of these agents of the circulation, and then inquire into the part which, each plays in maintaining the circulation of the blood.

Of the Bloodvessels.—The bloodvessels are of three kinds, *Arteries, Veins*, and *Capillaries.*

The *arteries* are the vessels which convey the blood from the heart. The etymology of the term (αηρ, τηρεω), shows that it was adopted at a period when nothing was known as to the real nature of the contents of these tubes during life. The fact that so large a proportion of the arterial system is empty after death, led to the opinion, which prevailed to the time of Herophilus, that it contained vital spirits, or air (*spiritus*, or πνευμα), during life, and the arteries were called πνευματικα αγγεια.*

Arteries are cylindrical tubes, whose walls are formed mainly by a high elastic material, whereby the cylindrical form is preserved

* This idea respecting the office of the arteries is thus expressed by Cicero. "Spiritus ex pulmone in cor recipitur et per arterias distribuitur, sanguis per venas."—*De Nat. Deor.* L. ii.

and the collapse of the tube is prevented. For the same reason when an artery is cut across, its mouth is patulous, and remains so.

The walls of arteries consist of three different textures: first, the external tunic, composed of areolar tissue, and commonly called the cellular coat; secondly, the middle coat, or fibrous tunic; and thirdly, the epithelial tunic.

The external tunic is that through the medium of which the artery is connected with neighbouring structures, and it also forms a nidus for the support of the nutrient bloodvessels of the arterial wall. These minute vessels, named *vasa vasorum*, are derived from neighbouring arteries; they ramify freely in the external tunic, and send minute branches to a certain depth in the wall of the artery. In a well-injected subject, they may be seen filled with injection on all the larger arteries, and when great vascular congestion has accompanied or preceded death, these vessels participate in the general plethora, and may be seen distended with blood on the aorta and its larger branches.

In some of the large arteries, a few pellets of fat may be found in the outer layers of the external tunic, which consist of very loose areolar tissue; the inner layers of this tunic are, however, very condensed, and adapt themselves closely to the middle coat of the artery to which they adhere intimately, probably by reason of the continuity of some of their fibres with those of the middle tunic. The same elements are found in the external coat of arteries, as in areolar tissue elsewhere, namely, the white and yellow fibrous tissue, but the former predominates in quantity so much that in some situations it seems to be the sole constituent of the tunic.

The extensibility, toughness, and power of resistance which this tunic enjoys, by reason of the large quantity of white fibrous tissue which it contains, adapt it admirably as the external investment of the arterial tube. It serves to give mechanical support to the other tunics, and being the medium in which the nutrient bloodvessels are distributed, it contributes to a certain extent to their nutrition. Hence there is no other tunic, the loss of which an artery suffers from so much; in diseased or injured states of the other coats, it preserves the integrity of the tube, and prevents any serious interruptions to the circulation; the wall of many aneurisms consists in great part of this tunic; and, on the application of a ligature, while the inner and middle coats give way under the pressure, this tunic resists and preserves its continuity for a time.

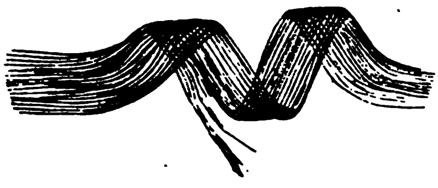
Of the Middle, or Fibrous Coat.—This tunic constitutes the principal portion of the arterial wall. It is in greatest part composed of yellow elastic fibrous tissue; but it likewise contains some white fibrous tissue, and also some of the unstriped muscular fibre.

When a large artery, as the human aorta, or the aorta of a horse or ox, is cut either longitudinally or transversely, two very distinct portions may be observed on examining the surface of the section with the naked eye. These are, an internal portion, quite yellow in colour, and constituting not more than a tenth or a twelfth of the

thickness of the whole tunic; and an external portion of a grayish-yellow colour.

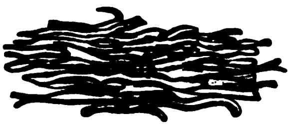
The internal portion, which we shall call *the longitudinal fibrous tunic* is composed of longitudinal fibres of yellow fibrous tissue, disposed in two planes, forming an internal and an external layer. The internal layer is in intimate contact with the epithelium, and consists of fine, pale, somewhat flat, not branching fibres, imbedded in a hyaline membrane, which peels off readily in the length of the vessel, and when separated from connection with the adjacent layer assumes a coiled form, as shown in Fig. 184. These fibres are not altered in any degree by the action of acetic acid. The external layer is composed of fibres of elastic tissue, which also take a longitudinal direction, but are much coarser, and branch freely, forming a very intricate interlacement (Fig. 185).

Fig. 184.



Finely fibrous layer of the longitudinal fibrous tunic of the aorta of the horse.—Magnified 200 diameters.

Fig. 185.



Coarsely fibrous layer of the longitudinal fibrous tunic of the aorta of the horse.—Magnified 200 diameters.

The external grayish-yellow portion of the fibrous coat of arteries forms nine-tenths or eleven-twelfths of the thickness of the wall of the artery, and may be distinguished from the internal portion by the name of the *circular fibrous tunic*. It consists entirely of transverse fibres, which surround the artery at right angles to its long axis. These fibres separate readily when pulled in the transverse direction. They form a series of concentric layers, in number proportioned to the thickness of the artery, composed of coarse yellow fibres which branch and interlace freely.

Fig. 186.

A portion of the circular fibrous tunic of the aorta of the horse, to show the reticulation formed by the interlacement of its fibres.—Magnified 200 diameters.

Upon fine transverse sections of the middle coat of one of the large arteries of man, or of the ox, we may observe the peculiar arrangement of these branching fibres which gives rise to the tendency of this coat to split into lamellæ. Certain large fibres or rods of yellow elastic tissue are disposed in successive concentric circles which pass transversely, and sometimes obliquely round the artery. (Figs. 187, 189, 190.) These branch in a penniform manner (hence we propose to call them *the penniform fibres*), and interlace with those on the same plane as well as with

those on an inner and outer plane. The branches again subdivide, and form by their frequent anastomoses that intricate interlacement which is represented in Fig. 187.

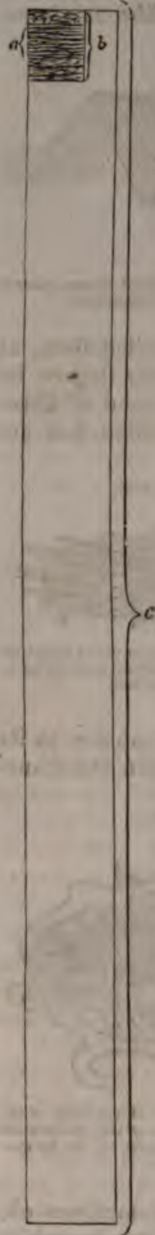
Fig. 187.

Section of the aorta of the ox, showing the arrangement of the two layers of the longitudinal fibrous tunic and of the circular fibrous tunic.—Magnified [illegible] diameters. *a.* The epithelial tunic. *b.* The internal layer of the longitudinal fibrous tunic. *c.* The external coarse layer of the same. *d.* A small portion of the circular fibrous tunic. Most of the fibres are cut across, but a few, which take an oblique course, are seen in their whole length, and their penniform branching is slightly indicated.

This disposition of the fibres may be particularly well seen on thin sections made from the dried aorta of the ox, and afterwards moistened with acetic acid. It is also sufficiently obvious in the aorta of the human subject, but the fibres are all very much smaller, nearly one-half the size of those of the ox, and the penniform subdivision is not so distinct.

Muscular Fibres.—Interposed between the layers of penniform fibres we find some of the wavy white fibrous tissue also arranged in a circular form, and intermingled with this are some transverse fibres of unstriped muscle, with oval nuclei, whose long axes are at right angles to the arterial canal (Fig. 191). These do not seem to form any single uniform layer, but are disposed probably on different planes (somewhat like the fibres of the dartos in the areolar tissue of the scrotum) among the fibres of the circular fibrous

Fig. 188.

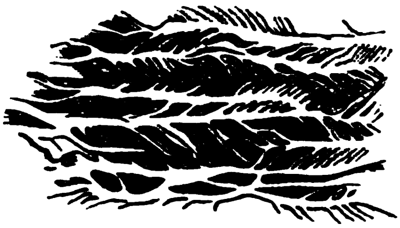


A section of the whole thickness of the artery, to show the relative extent of the portions of the wall shown in the preceding figure.—Magnified 40 diameters.

a. The coarsely fibrous portion of the longitudinal fibrous tunic. *b.* The longitudinal fibrous tunic and a portion of the circular fibrous tunic. *c.* The entire thickness of the artery.

and follow the same direction. They are best developed in es of the middle and smaller size, and may be most easily

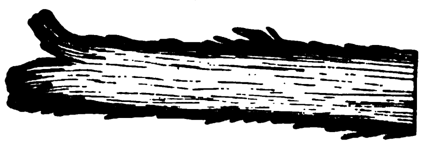
Fig. 189.



ion of the circular fibrous coat, showing the penniform branching of the large rods of elastic tissue, each large rod giving origin to multitudes of small interlacing fibres.—Magnified 200 rs.

ated from the fibrous tissue in arteries which have undergone decomposition. They are then seen to consist of long fusi- fibres of much delicacy, with a minute nucleus in most of them. e mass, they have the appearance represented in Fig. 191.

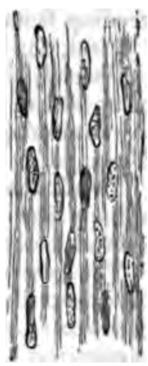
Fig. 190.



gle bar or penniform fibre from the circular fibrous tunic of the aorta of the ox, the small fibres been broken off.—Magnified 400 diameters.

e external layers of the circular fibrous coat become gradually and more like the ordinary yellow elastic tissue, the penniform he muscular fibres cease, and the true yellow elastic branching becomes continuous with that which is found aring quantity in the external coat.

Fig. 191.



Unstriped muscular fibres from the aorta of the horse.—Magnified 300 diameters.

ithelial Layer.—The interior of the arteries is ed by a single layer of delicate oval epithelial les, which separate very soon after death, and therefore, be sought for in quite recent sub- They may be best seen by scraping the inner ce of the artery. The long axis of each of particles is parallel to that of the vessel. are pointed, or, as it were, drawn out at their mities; and, according to Henle, they are some- elongated into fusiform fibres. They are re- able for the large size and the distinctness of nuclei which are often visible when the cell- cannot be detected. The particles seem to rest diately upon the innermost layer of the longi- al fibrous tunic, which bears the relation of a nent-membrane to them ; in this, when detached,

minute apertures appear constituting the fenestrated membrane of Henle. It is possible, as suggested by Henle, that this membrane arises from the transformation of the epithelium, which is ever drawing the materials of its formation and nutrition from the blood contained in the artery. Thus, it is not improbable that the innermost layers of the arterial wall, at least, are nourished from the blood flowing through the artery, and not from the blood of the *vasa vasorum*, which do not seem to penetrate to them. And this view is supported by observing that these innermost layers of the artery, *i. e.* the longitudinal fibrous tunic, are the seat of the atheromatous deposits which are so common in peculiar diatheses, or at an advanced period of life; these deposits being doubtless derived from the blood which traverses the artery.

Fig. 192.

Epithelial particles from the aorta of an ox.—Magnified 400 diameters.

Fig. 193.

Particles of epithelium and nuclei from the aorta of a horse; some of the former exhibit the elongated character.—Mag. 200 diameters.

From the preceding description, it would appear that the following tunics may be enumerated as constituting the wall of an artery proceeding from without inwards.

First, the external coat, consisting of areolar tissue.

Second, the circular fibrous coat, consisting of a series of lamellæ, composed of yellow elastic fibrous tissue, the most external of which are intermingled with white fibrous tissue and with circular muscular fibres.

Third, the longitudinal fibrous layer, which consists of two layers, a finely fibrous, and a coarsely fibrous.

And lastly, a layer of epithelium.

The internal layer of longitudinal fibres—which is the same as that described by Henle under the name of *fenestrated* membrane—constitutes, along with the epithelium, the internal tunic so long recognized by anatomists.

The elastic reaction of arteries is evidently resident in the middle fibrous coat, and in the same tunic the contractile power of the artery resides. The existence of these two forces in the arterial

wall, the one of simple elastic reaction, the other of a slow muscular contraction, is shown by the well-known experiments of John Hunter. A piece taken from each of the large arteries of a horse, bled to death, was laid open and extended on a flat surface without stretching; it was then measured, and afterwards subjected to strong tension; it was then measured again; on the removal of the stretching force, it failed to recover itself to its first dimensions by a notable difference. When an animal has been bled to death, the arteries are in their greatest state of contraction, the quantity of blood circulating in them being reduced to a minimum. This state of contraction, Hunter assumed to be the result of muscular force, and with good reason, as, after stretching, the artery did not contract to its previous dimensions. The stretching destroyed the muscular force, leaving whatever contraction would take place on the removal of the stretching, to be effected by the elastic force. Thus a piece of the aorta of a horse, when slit up and opened on a plane surface, measured five inches and a half; on being stretched, it lengthened to ten inches and a half; the stretching power being removed, it contracted again six inches, "which," says Hunter, "we must suppose to be the middle state of the vessel."* These powers inherent in the arterial wall, of yielding under a distending force, and reacting upon its contents with a force equal to that of the primitive disturbing one, and also that of muscular contraction, exercise an important influence in promoting or directing the circulation of the blood through the arterial system.

The elastic element of the arterial tunic is always developed in the direct ratio of the size of the artery; and the muscular element, although perhaps not bearing an inverse proportion to the size of the artery, yet becomes more prominent and distinct as the elastic tissue diminishes in coarseness and in strength. Thus it is in the smaller arteries that we notice the most perfect arrangement of muscular fibres, and in these the fibrous tissue is reduced to its internal longitudinal fibrous layer, the external circular fibres having disappeared.

Bloodvessels and nerves are freely distributed to the arterial tunics. To the former, allusion has already been made in describing their external tunic. We have no evidence that these bloodvessels penetrate further than to a slight depth into the fibrous tunic. It is probable, therefore, that they are destined to nourish the external tunic, and a portion (chiefly the muscular element) of the fibrous tunic, leaving the remainder of the arterial wall to imbibe its nutrition directly from the blood itself. The general arrangement of the nerves on the outer coat of arteries has been already described (vol. i. p. 223, and vol. ii. chap. xx.). The plexuses formed are chiefly conducted by the arteries to parts beyond; but they also furnish filaments penetrating to the muscular fibres, and bringing these into relation with the nervous system.

The arterial system may be described as taking its starting-point from the heart, by the attachment to that organ of each of the two

* Hunter on the Blood, Inflammation, &c., 4to. ed. p. 124, *et seq.*

great vessels (the aorta and the pulmonary artery) which form the main trunks of their respective systems. The middle coat of each of these vessels is inserted into or adherent to the concavity of three festoons composed of rounded cords of white fibrous tissue. To the central portion of the convexity of each of these the muscular fibre of the heart adheres closely in the case of the pulmonary artery; but in that of the aorta, one festoon and the half of another gives attachment to muscular fibre, whilst the other half of this festoon, and a third are attached to a part of the fibrous zone, which forms the base of the inner lip of the mitral valve. Along the line of these festoons the lining membrane of the heart, becoming continuous with that of the arteries, forms three semilunar curtains, which are strengthened by processes of fibrous tissue continuous with the festoons. These folds constitute the *valves* of these vessels, the only ones of the arterial system. We shall recur to these by and by.

Arteries convey the blood to the various parts of the body by the subdivision of their trunks and the giving off of branch-vessels at various points. The branches for the most part come off at an acute angle with the continued trunk, so that the new stream of blood does not experience any great diversion from the direction of its parent stream. In a few instances, however, this arrangement is not observed, as in some of the intercostal and lumbar arteries, which form nearly a right angle with the aorta from which they originate.

Anastomoses of Arteries.—The manner in which different arterial trunks communicate with each other indirectly, is one of the most interesting points in the anatomy of the arterial system. This *anastomosis* of arteries often affords the means of supplying the nutrient fluid to a limb after its principal artery has been obliterated, small collateral channels enlarging more or less for the reception of a greater supply of blood than they were wont to convey. Hence the study of the intercommunicating vessels has had great influence upon the surgical treatment of aneurisms and wounds of arteries.

One of the most simple of these anastomoses is found in the union of two arteries, originating from different trunks, to form one—as the vertebral arteries unite to form the basilar; another kind is, when two vessels from the same or different trunks form by their union an arch from the convexity of which others come off, which form similar reunions and arches, giving off smaller branches which take a similar course, and the arrangement continues to be repeated until the resulting branches are reduced to a very small size, when they pass into the capillary system. This mode of frequent subdivision and anastomosis is seen in the arteries which convey blood to the intestine—the mesenteric arteries. A third form is where two neighbouring arteries communicate by a distinct vessel, which passes from one to the other. By such vessels the remarkable anastomosis at the base of the brain, the circle of Willis, is formed. The anterior cerebral arteries passing upwards and forwards are united by a cross branch, the anterior communicating artery, and the carotid artery on each side is united to the posterior cerebral artery by a branch which

passes from before backwards—namely, the posterior communicating artery. By this free communication of the arteries in front with those behind, and of those on the right with those on the left, the brain is protected against loss of blood, if any of the main channels of its supply should be stopped.

The most common form of anastomosis is found in the limbs. Two principal channels convey blood to a limb, as in the forearm, the radial and ulnar arteries. The branches of these arteries communicate at various points, especially in the vicinity of the joints, and thus, if any impediment occurs in either, the other enlarges, conveys an increased quantity of blood, and even the obstructed trunk beyond the point of obstruction receives a supply by the anastomosing branches. Or the single main artery of a limb, the femoral, or the brachial, by its branches communicates with arteries which, originating from different sources, pass into another portion of the limb. Thus, in the thigh, the circumflex branches of the profunda anastomose with branches which descend from the gluteal, sciatic, and obturator arteries, which are branches of the internal iliac. Hence an obstruction in the femoral, high up, or even in the external iliac, will not deprive the limb of its due supply of blood, for the arteries just named will convey blood to the branches of the femoral, which arise below. This anastomosis may compensate for an obstruction in the internal iliac near its origin, and by a reflux of blood from the femoral through the profunda arteries supply the lower part of that artery. In the treatment of wounded arteries, the surgeon must always make allowance for the anastomoses in the neighbourhood of the wound. It rarely happens that a single ligature on the cardiac side of the wound is sufficient to guard against secondary hemorrhage; the anastomotic branches which arise from the main artery above the wound supplying the vessel or its subdivisions below, so that the blood finds its way by a reflex course to the distal part of the trunk of the artery, and to the wound. This is very apt to occur in wounds of the brachial artery at the bend of the elbow. The only and the obvious method of guarding against such an effect of arterial anastomosis, is to apply a ligature to two points of the artery, viz., below the wound, as well as above it.

The supply of blood to various segments of the body through different channels, and the free communication of these channels with each other, must be regarded as one of the most beautiful of the various mechanical contrivances in the human body. By such an arrangement a considerable security is obtained against the failure of the nutrition of the limb by the stoppage of one of its channels. And modern surgery is largely indebted to it for one of its most brilliant triumphs.

The passage of the blood into a limb or organ through various channels serves to distribute it more equally, and to relieve the elementary constituents of the limb or organ from the impetus which the entrance into it of a single large column of blood would occasion. This provision is especially secured for the brain by the subdivision of the four great streams of blood which enter the cranium

into several minor ones at the base of that organ, which again undergo extreme subdivision before they penetrate the nervous matter. In animals that hold their heads low, the subdivision of the carotid and of the vertebral arteries is very remarkable, and gives rise to the formation of the different kinds of *rete mirabile*. The most remarkable instance of the subdivision of arteries, prior to the penetration of the tissue they are destined to nourish, is that described by Sir A. Carlisle, in the Sloth, which seems to be connected with the extraordinary power enjoyed by those animals of sustaining muscular action for a lengthened period.

The anastomosis of the smaller arterial ramifications are also of great importance in many of the organs and tissues, especially under the skin and mucous membranes. Here a membranous expansion is supplied by a great number of distinct twigs which form a plexus everywhere continuous, and which again gives rise to other smaller plexuses before the ultimate capillaries are given off. To this form of anastomosis of the smaller arteries may perhaps be ascribed the tendency of some inflammations of membranous parts to be propagated rapidly along an extensive surface, as in erysipelas. In some organs, as the kidney, the arterial twigs have no anastomosis whatever.

Of the Veins.—The veins carry the blood back to the heart from the various tissues and organs. As the arteries divide and subdivide, the veins follow a contrary course. They commence from the capillary plexuses of the tissues and organs by minute radicle vessels, which by their junction form larger ones, and these again unite to form still larger ones; and so by the fusion of the smaller veins larger trunks are produced, until at length the venous blood, from all parts of the body, is returned to the heart by two great venous trunks, the superior and the inferior *venæ cavæ*.

Veins are much more numerous, and for the most part more capacious than arteries. In the extremities and the trunk they are arranged upon two planes, a superficial plane and a deep-seated one; the latter accompanying the deep-seated arteries, the former being immediately subjacent to the skin. The superficial veins are more numerous and present greater variety, both as to number and arrrangement, than the deep veins. Their smaller radicles anastomose in the same manner as has been just described in the arteries.

A distended vein has a cylindrical form, which, however, in some is interrupted here and there by a knotted appearance, caused by its enlargement at the situation of its various sets of valves. The coats of veins are essentially the same as those of arteries, but are less developed. Proceeding from without inwards, we find, first, an external tunic, composed of a thin layer of areolar tissue, answering in structure, position, and function to the external coat of arteries. Secondly, we find a fibrous tunic of which the outer portion consists of circular fibres ; the inner portion of longitudinal fibres both coarse and fine. The circular fibres are but slightly developed ; they are of the same nature as those in arteries and in the larger veins, and exhibit somewhat of the penniform disposition, which we have de-

scribed in the fibres of the arterial circular tunic. With them are mingled unstriped muscular fibres in less quantity but of precisely the same form and character as those in arteries. In the veins near the heart, these circular fibres are replaced by similarly disposed muscular fibres of the striped kind, continuous with and resembling those of the auricles.*

The longitudinal fibres are well developed, consisting of the outer coarse layer, which, in the large veins, as the cava ascendens, are arranged in the form of large bundles, parallel to the long axis of the vessel, and the internal layer or fenestrated membrane, which in every respect corresponds to the internal longitudinal fibrous layer of arteries. Upon this is placed the epithelium, which is precisely the same as that of arteries.

The imperfect development in veins of a tunic possessing much elastic power, like the circular fibrous coat of arteries, explains the readiness with which these vessels collapse, and the general thinness of the fibrous and areolar tunics accounts for the diaphanous character of the venous wall.

In a large portion of the venous system peculiar processes, called valves, are found projecting into the interior of the vessel at various points. These processes are semilunar, attached by their convex border to the wall of the vein, and free at their concave border, which is a little thickened. They are disposed in pairs in immediate juxtaposition—sometimes there are three placed together. They are most numerous in the superficial or subcutaneous veins; and are more so in the veins of the lower half of the body than in those of the upper. The smallest veins are destitute of valves; as also are the largest, as the cavæ. The pulmonary veins, those of the liver, and all the veins which contribute to the hepatic portal system, the splenic and mesenteric veins, want valves. The renal veins are also devoid of them.

The tissue of which these valves are composed is the same as the longitudinal fibrous coat of the vein, covered by a layer of epithelium; the valves cannot be properly described as reduplications of the inner membrane of the veins, they are processes of it.†

Of the Capillaries.—The system of vessels which is intermediate to the veins and arteries, is called by the name capillary, from the minuteness of their size. The finest arteries, and the finest veins likewise, receive this appellation. But the true capillary system is distinguished by a speciality of arrangement and an uniformity of size, proper to each tissue or organ.

The capillary vessels may be examined in injected specimens, or in recent transparent tissues, as in the pia mater, or in living transparent tissues, as the web of the frog's foot, the mesentery or dis-

* Rauschel states that these fibres can be traced in the superior cava, as far as the clavicle, and in the inferior as far as the diaphragm, and in the pulmonary veins as far as the first subdivision of each.

† We have great pleasure in referring to an excellent article on the anatomy of veins, in the 42d part of the *Cyclopædia of Anatomy and Physiology*, by Dr. S. J. Salter.

tended urinary bladder of the frog, the tail of the newt, the gill of the tadpole, the tail or fins of fishes.

The diameter of the capillaries varies in different textures from the $\frac{1}{1000}$ of an inch, to $\frac{4}{4700}$, according to the measurements of Weber.

The finest capillaries are found in the brain (Fig. 195, A) and in the retina; those of muscles, especially the cross branches which intersect the fibres, are likewise very fine. Among the largest are those of the lung and liver.

Fig. 194.

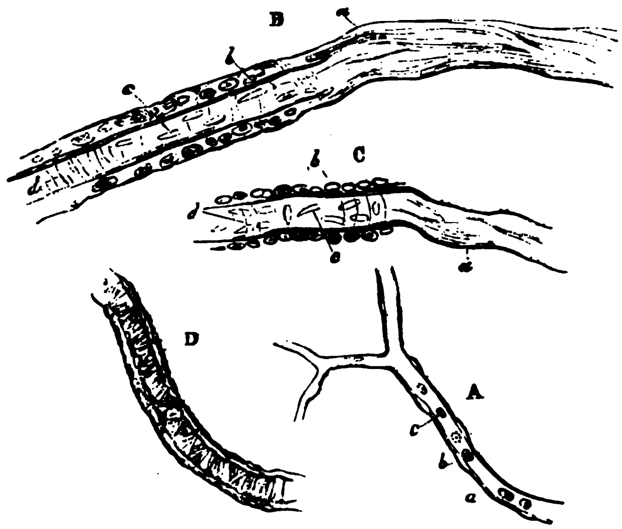
Arrangement of the capillaries on the mucous membrane of the large intestine in the human subject.—Magnified 50 diameters.

The capillaries form a network in each tissue or organ, which derives its nourishment directly from them, and they exhibit an arrangement adapted to the disposition of its proximate elements. In the tissues which assume a fibrous form, as muscle, nerve, fibrous tissue, the capillaries are disposed in lines parallel to the fibres, and these parallel vessels are united at variable intervals by cross branches, which pass at right angles to the fibres. (See Figs. 47, 95, 161, 162, and 194.) In compound or involuted mucous membranes, the capillaries form a plexus with more or less circular meshes, which correspond in form and size to the arrangement of the membrane—good examples of this are found in the mucous membrane of the stomach and of the intestines (Fig. 194). When the elements of the mucous membrane are prolonged into processes, forming villi or papillæ, each villus or papilla is found to possess its plexus or system of minute capillary vessels (Figs. 161 and 162). In the simple mucous membranes, and in serous membranes, the plexus of capillaries placed in the submucous or subserous areolar tissue exhibits large and irregular meshes.

In the compound tissues the capillaries have no direct relation to the ultimate anatomical elements—that is to say, these minute vessels do not ramify among the ultimate particles of the tissues. It is with their proximate elements they connect themselves. Thus in muscle the vessels lie between the fibres, and are separated from the sarcous particles by the sarcolemma; in nerve, in the same way, they are separated from the nervous matter by the tubular membrane; and in the vesicular matter they play around the vesicles and do not penetrate them. In most of the mucous membranes, the basement-membrane is placed between them and the epithelium, their nidus being the sub-basement tissue. So, also, with the serous membranes. In bone, the finest vessels are very remote from a large portion of the constituent osseous particles; ramifying through Haversian canals, they come in contact only with the osseous particles of those layers which immediately invest each canal; or with the periosteal or medullary layers. Vessels do not penetrate articular cartilage at all, which must therefore draw its nourishment from the vessels of neighbouring tissues.

The finest capillaries, such as may be most easily examined in connection with the pia mater of the brain, appear to consist of a

Fig. 195.



A. A capillary vessel from the vesicular matter of the human brain. *a.* Homogeneous wall. *b.* Nucleus of the wall. *c.* Red blood-corpuscle.
B, C. Different appearances of small arteries and veins of the human pia mater. *a*, *a*. Homogeneous membrane. *b*, *b*. Circular fibres. *c*, *c*. Oval nuclei of the internal epithelium, here about to cease. *d*, *d*. Transverse indications of the circular fibres.
D. Capillary artery from the mesentery of a rabbit.—Magnified 200 diameters.

homogeneous tissue, interrupted at short intervals by nuclei which adhere to, or are imbedded in the wall of the vessel. (Fig. 195, A.) These nuclei are mostly oval—sometimes nearly circular; most of them have their long axes directed parallel to the course of the vessel, but some are placed transversely. In some of these fine capillaries, very faint indications of a circular striation may be seen.

In some larger vessels, which perhaps may with more propriety be regarded as capillary arteries, rather than as true capillaries, a distinct arrangement of circular fibres may be seen. These fibres are flat, uniform in diameter, devoid of nuclei, and in all respects, but this, resemble the unstriped muscular fibres.

It had long been a question among physiologists, whether the capillaries, had proper walls distinct from the tissues to which they supplied blood. The microscope has settled this question in the affirmative, for most of the tissues and organs of the body; but it may still be doubted whether the finest capillaries of the liver have walls distinct from those cubical masses of epithelium which they permeate.

Although it is the rule that an intermediate system of vessels exists between the arteries and veins, we find two remarkable exceptions to it. One is in the erectile tissue of the penis; the other in

the uterine circulation. In both these instances, the arteries communicate directly with the veins. In the penis, the ramifications of the arteries pour their blood into the cells of the corpora cavernosa; in the uterus the small curling arteries of Hunter open directly into large venous sinuses, which in the gravid uterus form an intimate relation of contact with the villous processes of the placenta. These points will be fully described in the chapter on Generation.

It is not improbable that further research may detect a direct communication between arteries and veins, even in tissues, the greatest part of which is furnished with a true capillary plexus. In the cancellated structure of bone, and the diploe of the cranial bones, it seems highly probable that the arteries communicate immediately with the veins at many points. Mr. Paget* describes a direct communication between the arteries and veins of the wing of the bat, without any intermediate capillary plexus.†

Of the Heart.—This hollow muscular organ, which, like a forcing-pump, drives the blood throughout the vascular system, varies in its constitution, according to the complexity of the circulation, from a simple muscular tube, such as the dorsal vessel of insects, to the complex double heart of man, with its four cavities and its beautiful apparatus of valves.

The dorsal vessel of insects is the most simple condition of the heart. It consists of a muscular tube provided with certain valves, disposed like those of veins; these, by affording an obstacle to the flow of the blood in one direction, determine the course in which it is propelled by the contraction of the muscular wall, namely, towards the head. It is situated along the middle of the back, whence its name. At the points which correspond to the situation of the internal valves, it exhibits distinct constrictions, which in some insects are so marked, that the vessel appears to consist of "a series of slightly conical segments, partially sheathed one upon the other." (Owen.) The

---

* Lectures on Inflammation.

† The communication between arteries and veins by capillaries was not known to Harvey. In his time, and for a long period afterwards, anatomists supposed the blood to pass into the parenchyma of the tissues, whence it was received or withdrawn by the veins. Malpighi (about 1687), by microscopic examination, first demonstrated the intermediate capillary system in the lungs and urinary bladder of the frog. Leuwenhoek afterwards (1729) pursued this investigation, and has given some good illustrations of the capillaries examined in transparent parts during life.

Dr. Hales, in this country, many years later (1769), gave a very accurate description of these vessels, and denied altogether the idea of the intervention of a parenchyma, or, in his own words, of "glandular cavities." See his *Hæmastaticks*, p. 148, § 9, vol. ii. W. Cowper, the distinguished myotomist, also made observations on the capillaries of the transparent parts of warm-blooded animals, as the mesentery of a dog, and the omentum of a cat. Haller threw great light upon the subject, and by his facts and arguments, settled the question as to the direct continuity of arteries and veins. Subsequently (1745), Lieberkühn advanced our knowledge of the capillaries by his numerous injections, most of which are still extant at Vienna. In more recent times, the distinguished Prochaska seems to have been the first to form a just appreciation of the extent of the capillaries, and of their exact relations to the elements of the tissues. His description of the disposition of these vessels, based upon the examination of Lieberkühn's and his own injections, can scarcely be surpassed in the present day. See the 9th chapter (*de vasis saguin. capillar.*) of his Disquisitio Anat.-Phys. Organismi Corporis Hum. ejusque Processus Vitalis. Vienna, 1812. Bichat, indeed (1801), had erected these vessels into a system intermediate to that of the arteries and of the veins, but no anatomist who compares the descriptions of the two writers will hesitate to give to the former the merit of a more intimate practical knowledge of the anatomy of these vessels.

is propelled to the head through a tubular prolongation of the dorsal vessel, corresponds to the aorta; this divides into numerous branches, which soon lose selves in the areolæ, or diffused sinuses, which occupy the spaces between the s of the insect; from these sinuses, as from veins, the blood is returned to the , and enters that tube at several points, at its posterior or caudal extremity, as s at several apertures which are found on each side of the dorsal vessel, near the s of attachment of the valves.

Crustacea, the heart is likewise of a very simple form. In some of the lower acea it is simply a muscular vessel, as in insects; in the higher animals of this as in crabs and lobsters, it forms a distinct muscular cavity, or ventricle, giving to arteries, and pierced by several venous orifices through which the blood is d from the large venous sinuses which receive it on its return from the body. situated, as in insects, beneath the enlargement of the back.

the Molluscous classes the heart still retains great simplicity of structure. In the t of these, as Tunicata, it is still a muscular vessel, propelling the blood through ies which ramify on the respiratory organ, whence it is taken up by veins, and ned to the heart. In the compound Ascidians, we meet with the remarkable omenon of the oscillation of the currents of the circulation, under the influence of nge in the direction of the peristaltic contractions of the heart.

the Acephalous mollusks, we first observe the subdivision of the heart into two artments, or cavities; an auricle which receives the blood from the veins and mits it to a fusiform ventricle which drives it to the various parts of the body. In f the most highly organized of the Acephalous mollusks, *Venus chione*, Professor describes two auricles, which receive the blood from the veins of the gills, and mit it to the single fusiform ventricle, which is perforated by the rectum; and in enus Arca, the ventricle is divided into two cavities, having the rectum in the inter-. An artery is continued from each extremity of the ventricle, which distributes xygenated blood over the viscera, the muscular system, and the mantle. The of the Gasteropoda, likewise, consists of a single ventricle, which propels the blood e viscera and the muscular system of the body, and receives it from the branchiæ e, and sometimes by two, auricles.

the Cephalopoda, the most highly organized mollusks, the general plan of the is the same as in the Gasteropoda. The venous blood is received from all parts body by great venous sinuses, which also take up the blood from the gills; these communicate with the heart, which consists of a single cavity, whence arise the nain arteries of the body, called the *superior* and *inferior* aorta.

Fishes, the heart consists of two cavities; one, large, loose, and thin-walled, receives the venous blood—the *auricle;* the second, thick and fleshy—the *ven-* whence an artery springs, the first portion of which, dilated and surrounded by muscular fibres, constitutes what is called the *aortic bulb.*

the Batrachian reptiles there are two auricles, one which receives the blood from eins of the body—the *systemic auricle;* the other, which receives it from the lungs *ulmonic auricle.* Both auricles communicate with a single ventricle, whence the l is propelled throughout the body, as well as to the lungs. In Serpents, the presents a similar structure; but in the Python the ventricle is divided by an rfect septum into two chambers, one of which communicates with the aorta, other with the pulmonary artery. In the Saurian reptiles, likewise, there wo auricles, and a ventricle, which latter is subdivided into two or more cavities, nunicating with each other, and with certain arteries which spring from them— pting in the American alligator (*Crocodilus lucius*), in which the existence of a ct septum creates two distinct ventricles.

Birds and Mammals, the heart exhibits its highest development, consisting, as it of two auricles and two ventricles, separated by a complete septum; each auricle nunicating with its proper ventricle, and each ventricle giving rise to an arterial t.

'he human heart, in the adult subject, occupies an oblique posi- in the thorax. Its apex is directed downwards, forwards, and he left side, and in the quiescent state corresponds to the inter- between the fifth and sixth ribs. Its base corresponds to the rval between the third or fourth, and the eighth dorsal vertebræ, n which it is separated by the parts contained in the posterior

mediastinum. The base of the heart corresponds in front to the sternum, at about the level of the cartilage of the third rib.

The weight of the human heart in the adult is about 11 ounces for the male, and 9 ounces for the female (John Reid).

The two great arteries, the aorta and pulmonary arteries, spring from the base of the heart in front. Posteriorly, the base is formed by the auricles.

Both the anterior and the posterior surfaces of the heart are divided into two, by means of a groove which corresponds to the anterior and posterior margins of the septum of the ventricles, and which passes from base to apex. The anterior groove contains the left coronary artery and vein; the posterior, the right coronary artery and vein. These are accompanied by nerves. A transverse groove of considerable depth separates the auricles from the ventricles; it contains the coronary vein. All the grooves contain a greater or less quantity of fat, which envelops the vessels and nerves lodged in them.

Of the four cavities of the human heart, a ventricle and auricle are on each side of the median groove. The ventricles are cone-shaped cavities, their apices being directed towards the apex of the heart, their bases corresponding to the auricles. The left ventricle forms the apex of the heart. When the right ventricle is dilated, its wall extends to, and contributes to form, the apex. Each ventricle, when laid open, exhibits two distinct parts; one, which communicates with the auricle by a large and free aperture, called the *auriculo-ventricular orifice*, through which the blood passes from the auricle into the ventricle; the other, called *the infundibulum*, a funnel-shaped channel, which leads to the artery, and through which the blood is propelled into it from the cavity of the ventricle.

The Valves of the Heart.—The auriculo-ventricular orifice on each side is guarded by certain valves which, when not in action, lie in the ventricle. The valve of the left side consists of two triangular curtains, from the free margin and part of the ventricular surface of which tendinous chords (*chordæ tendineæ*) pass to various points of the wall of the ventricle. The bases of these curtains are attached along a fibrous zone, which separates the auricle from the ventricle. This valve is known by the name of the *mitral valve*, and the orifice is called the *mitral orifice;* the larger curtain is that which separates the infundibulum from the body of the ventricle. The valve at the right auriculo-ventricular orifice, consists of three portions, each having a pointed free extremity extending into the ventricle, and connected to its wall by tendinous cords. Hence this is called the *tricuspid valve*. The base of each segment corresponds to the fibrous zone which intervenes between the auricle and ventricle. Of the three curtains, of which the tricuspid valve consists, the largest is anterior, and the next in size corresponds to the infundibulum of the ventricle.

At each of the arterial orifices of the ventricles there are three valves of semilunar form (Fig. 199), which effectually close the mouth of the artery against the regurgitation of blood into the ven-

icle. Each of these valves has a convex border attached along e fibrous zone, which connects the artery to the infundibulum of e ventricle; and a free concave border divided by a small round dy of fibrous tissue (*corpus Arantii*) into two equal portions. As e blood flows from the ventricle, these valves lie up against the ll of the artery; but immediately the blood regurgitates towards e ventricle, they are pushed by it in towards the mouth of the tery; and their free margins, as well as a considerable portion of eir ventricular surfaces coming into close apposition, an effectual rrier is formed against the return of the blood. The semilunar lves of the aorta are essentially the same in all points of form d structure as those of the pulmonary artery; but those of the rta are the stronger.

The inner surface of the wall of the central cavity of each ven-icle is marked by very numerous fleshy columns (*carneæ columnæ*) ich project from it in relief. There are three orders of them; st, the simple column in relief, which adhéres throughout its whole ngth to the wall of the ventricle; secondly, the column, attached each extremity, but free in the interval, so that a probe or other strument may be passed beneath its middle part; and thirdly, the lumn attached at one extremity to the wall of the ventricle, and ojecting into its cavity by the other; these last are distinguished om the others by the name of *musculi papillares;* the chordæ ndineæ spring from their free extremities, and are inserted into e mitral and tricuspid valves, and one or two into the wall of the ntricle. The infundibular portion of the ventricle is perfectly ooth on its inner surface, and quite free from columnæ carneæ.

The auricles are thin-walled muscular bags, of irregular somewhat boidal shape. Each communicates by a wide orifice, with its cor-sponding ventricle, and is separated from its fellow by a thin fleshy ptum, which, at its middle, is so thin as to be translucent. At is situation an orifice existed during intra-uterine life, through ich a communication took place between the auricles (*foramen ale*, or *Botalli*). Each auricle has two distinct portions; the *sinus nosus*, which forms by far the greater portion of the bag, and the oper *auricle*, or *auricular appendage*, which appears like an off-oot from the former, somewhat in the shape of a dog's ear, pro-cting forwards on each side of the aorta and pulmonary artery. he veins pour their blood into the sinus venosus; the auricular pendage receives no bloodvessels, but its cavity communicates with at of the sinus venosus. The right auricle receives the two great ins of the system, and the great venous trunk of the heart, the *ronary vein*. The superior vena cava opens into the upper angle the right auricle, passing downwards and forwards; the inferior va opens into its lower angle, passing upwards, backwards, and wards. The coronary vein opens between the mouth of the infe-or cava and the auriculo-ventricular orifice.

On laying open the right auricle, by an incision extending between e two venæ cavæ, an intricate arrangement of muscular bundles, lled *musculi pectinati*, may be seen on its outer wall. These fleshy

columns interlace freely with each other. On the septum a depression exists about its middle, called the *fossa ovalis*, nearly surrounded by a thick fleshy ring called the *annulus ovalis*. This marks the situation of the orifice already alluded to, which existed during intra-uterine life—the *foramen ovale*.

To the left of the orifice of the inferior vena cava, there is a valvular process which is another remnant of a mechanism adapted to the circulation through the heart in intra-uterine life. This is the *Eustachian valve*. It is a process of the inner membrane of the auricle, of semilunar shape, which projects between the vena cava and the auriculo-ventricular orifice, and in the fœtus served to direct the ascending current of blood through the foramen ovale into the left auricle. The orifice of the coronary vein is guarded by a small valve called the *valve of Thebesius*. Several small orifices are seen scattered over the inner surface of the right auricle, called *foramina Thebesii;* some of these are the openings of small veins from the wall of the auricle; others merely lead into depressions between the muscular fibres of the auricular wall.

Four veins pour their blood into the left auricle; these are the right and left pulmonary veins, two on each side. The left veins open quite close to each other. The left auricle is placed in the concavity of the aorta, and has lying in front of it the roots of both the aorta and the pulmonary artery.

The inner surface of the left auricle is perfectly smooth, covered with an opaque lining membrane, which appears somewhat thicker than that of the right side. There is no appearance of musculi pectinati in the left sinus venosus; a few, however, exist on the inner wall of the auricular appendage. Here and there some orifices are seen, leading to depressions in the wall of the sinus venosus. On the left side of the septum, between the auricles, we observe traces of the valve-like portions of the septum, which formed the immediate boundary of the foramen ovale during fœtal life.

Of the Pericardium and Endocardium.—The heart is inclosed in a fibrous bag, the fibrous pericardium, which is closely adherent below, to the central tendon of the diaphragm, and above, becomes continuous with the external tunic of areolar tissue, which invests each of the large arterial and venous trunks that connect themselves with the heart. This bag serves to fix the position of the heart, and to prevent any sudden or extensive displacement, which might interfere with its proper action. It consists almost exclusively of white fibrous tissue.

Within this fibrous bag is a serous membrane, *the serous pericardium*, which resembles in all points of arrangement and structure the other membranes of its class. One portion of it invests the internal surface of the fibrous pericardium, while the other covers the heart, the line of reflection passing over the great vessels at the base of the heart.

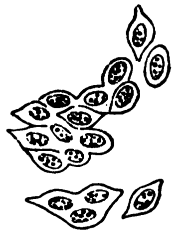
The cavities of the heart are lined by the endocardium, a membrane continuous with and closely similar to the lining membrane of arteries and veins. It consists of a layer of epithelium placed on a

um of fine fibres which exhibit minute wavings. The epithe- appears to be extremely delicate, but the same in all its cha- rs as that of the bloodvessels. It is so delicate, that to be satisfactorily it must be examined in animals just killed. We

Fig. 196.

Epithelium from the left auricle of the horse magnified 200 diams.), showing the two forms f particles, the round and the pointed.

Fig. 197.



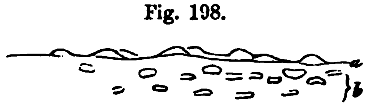
Epithelium from the left ventricle of the horse. —Magnified 200 diams.

rve two forms of epithelial particles, one soft, rounded, and lar, the other somewhat compressed, and drawn out at opposite into pointed or fibre-like processes (Fig. 196). It is difficult termine the precise relative position of these two forms of epi- um, but it seems probable that the pointed processes are the more ly seated, and are in immediate contact with the subjacent fibrous , which here corresponds to the basement-membrane beneath pithelium of serous and mucous membranes.

e endocardium of the left auricle, and of the septum and auri- appendage of the right auricle, is thicker and denser than that her parts of the heart. This is due to an increased development e fibrous layer beneath the epithelium, especially of its yellow ent. The precise meaning of the greater thickness of endo- ium in these parts of the heart is far from obvious.

f *the Structure of the Valves of the Heart.*—The valves of the t are formed by processes of fibrous tissue covered by epithelium. een the auricle and ventricle, as well as at the mouths of the and the pulmonary artery, there are remarkable developments brous tissue. Interposed between each auricle and ventricle is a fibrous zone, or ring, to which the muscular fibres of the le adhere on the one hand, those of the ventricle on ther. The fibrous tissue is nged inwards towards the y of each ventricle, so as to three curtains on the right tricuspid valve), and two on ft (the mitral valve). These

Fig. 198.



A portion of the aortic semilunar valve in the dog. *a.* Surface of the valve. *b.* Nuclei of the epithelium seen on its margin.

ns are continuous with the chordæ tendinæ, which appear to be ed into them at their margins, and at various distances from on the surface next to the ventricle, but not at all on that corresponds to the auricle. They are covered on both surfaces

by epithelium, which likewise extends over each of the chordæ tendineæ. The fibrous tissue at the orifice of the pulmonary artery, as well as at that of the aorta, consists of fibrous cords arranged as three festoons continuous with one another, the convexity of each being directed towards the muscular tissue of the infundibulum of the ventricle, and its concavity to the artery. On the right side, the muscular fibres of the infundibulum adhere to a small portion of the centre of the convexity of each of these festoons, and the circular fibrous coat of the artery seems closely attached to the whole extent of the concavity. On the left side, the fibrous festoons are connected partly with the muscular fibres of the ventricle, and partly with the base of the inner curtain of the mitral valve. The process of fibrous tissue extends from each festoon towards the mouth of the artery, forming a loose semilunar curtain, which is the basis of the valve. Each of these curtains presents a convex attached border, and a concave free border, interrupted at its middle, or bisected so as to form two concave borders, by a slight thickening of the fibrous tissue, which forms a small spherical body called the *corpus Arantii;* it also has a convex surface directed towards the ventricle, and a concave surface directed towards the artery. The bundles of fibres which constitute this fibrous basis of each valve are disposed in festoons, some parallel to the fibrous festoon of the attached border; others, and the greatest number, parallel to the smaller concave borders on each side of the corpus Arantii. The fibres nearest the attached border of the valve are considerably more developed than those near its free margin. Indeed, for a space of about three or four lines from the edge of the valve, the fibrous tissue is extremely thin, and almost transparent. It is at this part of their ventricular surface that the valves come in contact when they close the arterial orifices, forming a mutual support to each other, and leaving the main stress of the backward pressure of the column of blood in the artery, to be borne by that portion of each valve which intervenes between this and its attached border. Hence the greater thickness of the fibrous basis in this situation. It is worthy of notice, that the tissue of the endocardium is nearly, if not completely, identical with the inner longitudinal fibrous tunic of arteries; a fact which

Fig. 199.

Diagram of the semilunar valves of the aorta (after Morgagni). *a.* Corpus Arantii on the free border. *b.* Attached border. *c.* Orifices of the coronary arteries.

Fig. 200.

Fibrous tissue of a semilunar valve beneath the endocardium.

ins the close similarity between the diseased states of the arte-issue, and those of the endocardium and the heart's valves.

chanism of the Valves.—The valves are closed by the mere ulic pressure of the blood. When the blood accumulates in entricles, it pushes up the auriculo-ventricular valves towards uricle until their several portions come in contact with each , and close the orifice. But the simple contact of the curtains ese valves with each other, would not prevent regurgitation; ie same hydraulic pressure which brings them in contact would them into the auricle, were it not that their margins are con-d with the walls of the ventricle and the musculi papillares, by s of the chordæ tendineæ. When the ventricle contracts, it s firmly by means of the chordæ tendineæ upon the valves, and nly keeps them closed, but causes them to exercise a considera-ressure on the blood, which promotes its onward flow into the y.

us, by the attachment of the chordæ tendineæ to the several ins of the valves, not only is regurgitation of the blood op-l, but every part of the surface of each curtain is made to upon the blood, with a force equal to that of the contraction e ventricle, and to aid in propelling it through the artery. ld, however, any imperfection of the valve exist, as by the im-ct apposition of its several portions, a chink remains between margins, and regurgitation takes place to a degree proportionate size of the chink.

e semilunar or arterial valves are closed in their turn by the re of the blood from the artery, backwards, towards the heart. lood forcibly driven back by the elastic reaction of the arterial slips between the wall of the artery and the valves, at the s of Valsalva, and throws the latter inwards, causing them to and close the arterial aperture, thereby preventing regurgita-nto the ventricle. Thus the force by which the arterial valves osed, being the elastic reaction of the arterial walls, excited expulsive force of the ventricle, bears a constant ratio to the ctile power of the wall of the heart, and, therefore, the degree sion of the semilunar valves, and the sound which it develops econd sound of the heart), enables us to form an estimate of pulsive force of the ventricle, which is often of great value ctice.

the Muscular Tissue of the Heart.—The heart is composed scular fibres of very various sizes. In all essential points of ure, these fibres resemble very closely the striped fibres of ternal muscles, differing from them, however, in the extreme y of the sarcolemma. They interlace with each other in an te manner, and assume opposite directions on different planes, forming a complicated interlacement of fibres, which adds y to the power of resistance possessed by the organ. By this cement the fibres of the heart adhere to each other, for be-them there is little or none of that areolar tissue which exists nsiderable quantity in the external muscles, and unites their

fibres and fascicles together. This interlacement takes place irrespective of any subdivision of the fibres. Nevertheless, it has recently been noticed by Kölliker and other good observers, that a true anastomosis does take place between adjacent fibres by the branching of each fibre, and the fusion of neighbouring branches. A somewhat similar branching and anastomosis of the ultimate muscular fibre has been observed at the surface of the tongue, an organ of which the muscular structure is not unlike that of the heart.

The complicated disposition of the fibres of the heart on different planes has, no doubt, the object of strengthening the walls of its cavities, and insuring a uniformity and synchronousness in the contraction of all its fibres. This arrangement belongs particularly to the ventricles, where such a mode of action is most needed. It may be best demonstrated on hearts which have been subjected to long boiling. By this process the fibre is hardened, and may be readily torn in the direction of its course, and thus, by a little careful manipulation, the connection of the fibres and bundles of fibres may be unravelled.

The ventricles are covered by a thin layer of fibres common to both. These may be traced, apparently emerging from the apex, and spreading out over the anterior as well as the posterior surface of the heart. At the apex, these fibres pass in to form a connection with the fibres which form the innermost layer of the wall of each ventricle; from the same point these superficial fibres pass obliquely, those of the posterior surface from right to left; those of the anterior surface rather in the direction from left to right. At the transverse fissure, they sink in to attach themselves to the fibrous zone, which separates auricles from ventricles. According to some anatomists (Reid and others), many of the superficial fibres do not pass beyond the anterior longitudinal fissure, but sink into and become incorporated with those of the septum.

If the fibres of the apex be traced inwards, they are found to penetrate so as to form the innermost layers of the walls of the ventricle, contributing likewise to form the carneæ columnæ, and becoming attached to the fibrous structures of the ventricle, both to the chordæ tendineæ, and the auriculo-ventricular zone. Some of these fibres serve to connect opposite walls of the heart: thus, the deep layer of fibres of the posterior wall of the heart receives fibres from the superficial layer of the anterior wall, and reciprocally the superficial layer of the posterior wall contributes to the deep layer of the anterior. But others of the superficial fibres are continuous with the deep fibres of the same wall. These are the fibres which, in passing from the superficial to the deep portion of the wall, make a remarkable turn in figure of 8, of which the lower portion is very small, as described and figured long ago by Lower.

Between the superficial and the deep or reflected portion of the ventricular fibres, are some which have been described as the proper fibres of the ventricles; these pass round each ventricle in a circular direction, some obliquely, some at right angles to its axis; they form a sort of hollow cylinder for each ventricle, which is attached

above to the fibrous zone of the auricles, and is open below towards the apex. On the right side, a smaller number of circular fibres embrace the infundibular portion of the ventricle, attaching themselves to the fibrous festoons of the pulmonary artery.

Of the Muscular Fibres of the Auricles.—In the auricles, we find a common and a proper set of fibres. The former may be traced along the anterior surface of both auricles, embracing them like a belt, but not extending round to the posterior surface. The latter are arranged in several circular or spiral bands, some of which spring from the auriculo-ventricular zone, and return to it again, and envelop the auricle before and behind, passing sometimes at right angles to it, sometimes obliquely; others pass round the auricle in a horizontal direction, and parallel to the auriculo-ventricular zone. Each of the venous orifices of the auricles is surrounded by a series of circular fibres (sphincter-like) which are continued, as already referred to, to a considerable distance along the trunks of the veins, retaining in this latter situation just the same character as at the auricle itself. This is a good situation for seeing the branching and anastomosis of the fibres.

Nutrition of the Heart.—The heart is nourished by blood derived from the aorta. Its arteries, the right and left coronary arteries, are the first branches which spring from the aorta. They leave that vessel just beyond the margins of the semilunar valves. The right passes along the circular groove between the auricles and ventricles, and sends a branch down the posterior median groove to the apex; the left passes along the anterior median groove, anastomosing at the apex with the latter branches. Corresponding with the small size and the oblique direction of the heart's fibres, are an extreme closeness and an everywhere oblique sloping of the capillary network. From this, venous radicles are formed at various points, and unite into large veins, which are found in the grooves of the heart accompanying the arteries; these veins terminate in the coronary vein, which is lodged in the right portion of the circular groove, and opens into the right auricle, close to the orifice of the inferior vena cava.

Nerves.—The nerves of the heart are derived from the cardiac branches of the pneumogastric nerve, and from the sympathetic. These nerves form by their frequent anastomosis a plexus called *the cardiac plexus.* It is situated upon the aorta and pulmonary artery, just as they have issued from their respective ventricles, and is commonly described as consisting of two portions—*the superficial cardiac plexus*, which corresponds to the concavity of the arch of the aorta, and lies in front of the right branch of the pulmonary artery; and *the deep cardiac plexus*, which is much the larger portion, and lies behind the arch of the aorta, between it and the bifurcation of the trachea. To the formation of these plexuses, branches derived from the vagus and the sympathetic on both sides contribute.

The greatest part of the nerves which emanate from these plexuses entwine round and accompany the right and left coronary arteries, forming the anterior and posterior coronary plexuses. From these,

nerves pass to the auricles and ventricles, but chiefly to the latter. A ganglion, described first by Wrisberg, and called after him *ganglion cardiacum Wrisbergii*, is generally found in front of the left auricle, and behind the aorta. Scarpa has also described gangliform enlargements of the nerves on the anterior surface of the ventricles, to one of which, situated on the anterior surface of the horse's heart, half-way down the anterior groove, he refers under the name of "cardiaci sinistri ganglion insigne."* It is probable, however, that none of these latter enlargements are truly ganglionic in their nature.

Remak describes numerous microscopic ganglia on the nerves of the heart of the calf. We have seen some of these small ganglia upon the surface of the auricles in the calf's heart, although we have not succeeded in detecting them on the surface of the ventricles, nor in the substance of the septum, as delineated by Remak. We can vouch for the truly ganglionic nature of those which we have seen from the unequivocal existence of vesicular matter in them.†

Some elaborate dissections of the nerves of the heart have lately been made by Dr. Robert Lee,‡ from which it appears that the heart is more largely supplied with nerves than had been hitherto supposed, and that a larger number go directly to the muscular structure of the heart, independently of the arteries, than had been admitted by previous anatomists. Upon these nerves numerous gangliform enlargements may be seen, which Dr. Lee figures as of great size upon the nerves of the posterior surface of the heifer's heart.

Our own dissections§ enable us to confirm the general accuracy of Dr. Lee's delineations, although we have not discovered so many nor such large nerves as he depicts. We have likewise seen numerous swellings on these nerves, which again we have failed to find, either in such numbers, or of the same size as those represented in Dr. Lee's plates.

The nerves are composed altogether of gelatinous fibres, and the swellings do not contain vesicular matter; and, therefore, do not partake of the nature of ganglia. As filaments invariably pass from these swellings into the muscular structure of the heart, we would regard them as resulting from that loosening of the constituent fibres of nerve trunks, which invariably takes place just before branches are given off from them.

Of the Action of the Heart.—The action of the heart is remarkable for its rhythmical character. Each of its cavities exhibits a succession of contractions and dilatations, following each other with the most perfect rhythm. Cavities of the same kind contract or dilate simultaneously; but the ventricles are in contraction or *systole* when the auricles are in dilatation or *diastole*, and *vice versa*. Fol-

* Scarpa, Tabulæ Anatomicæ. Ticin. 1794. Tab. vii. fig. 1.

† Remak, Neurologischen Erlauterungen. Muller's Archiv. 1844. Tafel xii.

‡ Phil. Trans. 1849.

§ We take this opportunity of acknowledging the valuable assistance of our friend and pupil Mr. Samuel Martyn in these dissections.

owing the course of the circulation through the heart, the auricles aving been filled from the veins which open into them, contract and xpel their blood into the ventricles, which, in their turn, contract o drive the blood into the arteries. When the ventricles contract, he heart experiences a peculiar tilting movement, by which its apex s raised from the level of the sixth rib to the space between the fifth nd sixth, and at the same time it is rubbed more or less forcibly gainst the wall of the chest. The wall of the ventricles is firmly ontracted at every point, and rendered hard and tense; and, there- ore, in its movement it communicates a considerable vibration to the all of the chest, giving rise to what is called the *impulse*. This npulse is caused altogether by the systole of the ventricles, and he consequent movement of the heart; it is always directly pro- ortionate to the size of the ventricles, or to the extent of their urface in contact with the wall of the thorax, and to the vigour of heir contractions. According to Valentin's experiments, the tilting novement of the heart will take place even when the apex has been ut off, denoting that that phenomenon cannot be due to any recoil onsequent upon the resistance to the passage of the blood through he great vessels, and that its true cause is the contraction of the bres of the ventricle.

Certain sounds accompany the heart's action, the accurate inter- retation of which has shed a flood of light upon the diagnosis of iseases of that organ. On placing the ear over the region of the eart in a healthy individual, the following phenomena may be per- eived; first, a heavy, somewhat prolonged sound, which is synchron- us with the impulse, and is best heard over the heart's apex; this s the *systolic* or *first* sound; secondly, a short clicking sound imme- iately succeeding this; it is synchronous with (but not caused by) he diastole of the ventricles, and is called the *diastolic*, or second ound; it is best heard over the base of the heart near the root of he aorta. After this the heart seems to pause, as it were to take est, and then follows the first sound again, followed instantly by he second sound, and then the pause. The duration of the first ound is about double that of the second, while that of the second s equal to the pause. Thus, if the whole period of the heart's ction be divided into four parts, the first two would be occupied by he first sound, the third by the second sound, and the fourth by the ause.

Numerous experiments and observations have been made with eference to the question of the signification of these sounds. We nust here content ourselves with stating the conclusions which we hink may be safely drawn from them. The first sound is composed nainly of the muscular sound, generated by the contraction of the entricles, strengthened by that due to the sudden tension of the uriculo-ventricular valves over the blood contained in the ventricles, his tension being effected by the contraction of the carneæ columnæ, which is synchronous with that of the rest of the ventricular wall. To these causes of sound may be added the impulse of the heart

against the wall of the chest, and, perhaps, also the collision of the blood against the orifices of the great vessels.

The second sound is due to the sudden tension of the semilunar valves of the two great vessels, by the recoil of the columns of blood injected into them by their respective ventricles. An experiment, originally suggested by the late Dr. Hope, and repeated by several observers, proves this unequivocally. If in an animal whose respiration is maintained by artificial insufflation, the heart's action being thereby prolonged, a hook be introduced into the aorta so as to hold back one of its valves, and leave a passage for the regurgitation of a portion of the blood after each systole of the ventricle, a bellows sound becomes generated, which usurps the place of the clicking second sound. But the moment the valve is allowed to resume its play, the natural click returns.

That this is the correct interpretation of the sounds of the heart, is farther proved by the observation of the influence of various morbid states of that organ upon them. Thus the first sound is modified by whatever increases or weakens the intensity of the ventricular systole, of the impulse, and of the tension of the auriculo-ventricular valves; and when the latter takes place imperfectly, by reason of the insufficiency of the valves to close the orifices, the first sound is accompanied (not replaced) by a bellows-sound due to the regurgitation of blood from ventricle to auricle. Again, should one or more of the semilunar valves be so injured or altered as to prevent the complete closure of the arterial orifice, at the time of the diastole, the second sound is replaced by a bellows-sound, just as in the experiment above detailed.

The regular succession of the two sounds and the pause, bearing to each other the relative duration already mentioned, constitutes the rhythm of the heart.* Sometimes the pause lasts for a much longer period than a fourth of the whole, for as long or longer than would suffice for the development of the other two sounds. Under these circumstances the heart is said to intermit, and its rhythm is interrupted.

At every systole of the heart an impulse is felt in all the large arteries of the body, which is synchronous with the contraction of the ventricles, or so nearly that the difference is inappreciable, except in very distant arteries, as those of the tarsus. This impulse in the arteries constitutes the pulse—which will be fully described by and by, and which, from its general accordance with the heart's action, affords the readiest means of judging of the heart's rhythm, and counting the frequency of its action.

When the rhythm of the heart is regular, this succession of first and second sound (systole and diastole) and pause may be heard a certain number of times in a minute in each individual, and by a series of observations, the scale may be formed showing the average frequency of the heart's action at different periods of life in man. This is shown in the following table, which is that formed by our able friend

* Some observers admit the existence of a short pause after the first sound.

and colleague, Dr. Guy, from a comparison of numerous observations.*

TABLE OF THE AVERAGE FREQUENCY OF THE HEART'S ACTION, AND OF THE PULSE AT DIFFERENT AGES.

At birth	140
Infancy	120
Childhood	100
Youth	90
Adult age	75
Old age	70
Decrepitude	75–80

In general, the frequency of the heart's action and of the pulse in the female exceeds that of the male, after the seventh year; if the average pulse of the adult male be stated at 70, that of the adult female may be put down at 80.

The heart's action is seldom less frequent than 45 or 50 in health; Heberden has counted it as low as 42, 30, and even 26, in healthy males; and Fordyce counted it in one case 26 in an old man, and in another 20. In cases of chronic disease of the brain it falls very low. We have ourselves counted it as low as 16 in one of these cases for months together.

According to the researches of Drs. Knox and Guy, the frequency of the heart's action (and the consequent frequency of the pulse) varies at different periods of the day. It is most frequent in the morning, and becomes gradually slower as the day advances. The diminution is most marked at night.†

Posture exercises a remarkable influence on the frequency of the heart's action. The law is, that the frequency is the greatest in the erect position, next to that in the sitting, and least in the horizontal posture. The following table has been framed by Dr. Guy from the results of sixty-six observations in the male, and twenty-seven in the female.

TABLE OF THE FREQUENCY OF THE HEART'S ACTION IN DIFFERENT POSTURES.

	Standing.	Sitting.	Lying.	Differences.
Males	81	71	66	10, 5, 15
Females	91	84	80	7, 4, 11

These observations denote the curious fact that posture influences the frequency of the pulse less in the female than in the male; and from another series of more numerous observations, Dr. Guy deduces that the effect of change of posture on the frequency of the heart's action in the male is more than twice as great as in the female.

The cause of this difference in the frequency of the pulse in different postures resides probably in the effort employed to maintain the muscular contractions necessary to support the erect or sitting postures. But careful experiments are still wanting to ascertain whether a simple difference of posture, without muscular exertion,

* Art. *Pulse*, Cycl. Anat. and Phys.

† See Graves's Dub. Hosp. Rep. vol. vi., and Dr. Guy's art. *Pulse*, Cyclo. Anat. and Phys.

would develop a change in the frequency of the pulse. Those as yet done by the revolving board, seem to have had reference only to the exertion of muscular force in the production of the *change* of posture, and not to that required for the continued effort to maintain the attitude.

The Course of the Circulation in the Adult.—Taking the left ventricle as the starting-point for the circulation, we may describe the blood as pursuing the following course. By the left ventricle it is driven through the aorta into every artery of the body save the pulmonary; and having passed through the capillary system it enters the venous radicles, and from them it passes to the venous trunks; it is at length returned by two great trunks, the superior and inferior *venæ cavæ*, to the right auricle of the heart. This portion of the circulation, from its traversing the whole system, except the lungs, and from its occupying by far the largest part of the body, is called the *systemic* or *greater* circulation. The venous blood, brought by the great venous trunks to the right auricle, is expelled by that cavity into the right ventricle, which drives it by the pulmonary artery through the lungs to the pulmonary veins, through which it passes to the left auricle, and so on to the left ventricle. This portion of the circulation, traversing only the lungs, and connecting the right ventricle and left auricle, forms the *lesser* or *pulmonic* circulation.

Of the Portal Circulation.—In general, the arterial blood passes through a single system of capillaries and veins before it is returned to the auricle. But there are two remarkable exceptions to this—one in the portal circulation of the liver, the other in the kidneys. In both these cases, the blood passes through two subsystems of capillaries after it leaves the arteries. Thus, as regards the hepatic circulation, the blood conveyed to the intestines by the arteries, passes through the intestinal capillaries into the intestinal veins, whence it passes to the trunk of the vena portæ, which again transmits it to the hepatic capillaries, and thence to the hepatic veins, through which it reaches the heart. A portion of the circulation, of which the chief vessel is formed like a vein, and distributes its blood like an artery, is called a portal circulation. A similar circulation is found in the kidneys. The afferent arteries end in the Malpighian tufts, whence the blood is taken up by the efferent veins, which quickly break up like arteries into another capillary plexus surrounding the uriniferous tubes, and this plexus gives origin to the radicles of the renal or emulgent veins.

The hepatic portal circulation, however, has several points of communication with the systemic veins, or the inferior vena cava; and thus it happens, when from disease of the liver a considerable portion of the portal system of that organ is obstructed or obliterated, that a part of the blood from the intestinal canal finds its way into tributary veins of the cava, and returns by that route to the right side of the heart. The points of communication are between the veins of the cava (left renal) and of the intestines, especially the colon and the duodenum, and between the inferior mesenteric and the

hemorrhoidal veins, a fact which explains the frequent occurrence of hemorrhoids in obstructions of the liver; also between superficial branches of the portal veins of the liver, and the phrenic veins, as pointed out by Kiernan.

Bernard states that immediately after the portal vein has entered the liver, and sometimes before, a certain number of branches are given off from it, which, entering the liver, some superficially, others more deeply, form communications with the vena cava.

Of the Fœtal Circulation.—In the fœtus in utero, the course of the circulation is greatly modified, by reason of the inaction of the lungs as aerating organs, and the consequent imperfect attraction of the blood to them. During intra-uterine life, the aeration of the fœtal blood is effected by the placenta, a highly vascular organ, in which the fœtal blood is brought into a very close relation to the maternal blood as it circulates through the wall of the uterus. The placenta, therefore, is in effect the lung of the fœtus, and bears a corresponding relation to its circulation.

A large portion of the fœtal blood is carried to the placenta through the umbilical arteries, which are continuations of the trunks of the internal iliac arteries escaping from the body of the fœtus through the umbilicus. From the placenta the blood is returned to the fœtus by the umbilical vein, which is bound up with the umbilical arteries in the umbilical cord, and enters the body of the fœtus at the navel. From this point the umbilical vein passes upwards and to the right side under the liver, in its longitudinal fissure, and at its transverse fissure it joins the sinus of the vena porta, through which most of its blood is distributed to the liver. One large branch, however, follows the course of the original trunk in the posterior part of the longitudinal fissure, and opens into the inferior vena cava just before that vessel communicates with the heart. This vessel is the *ductus venosus*—a continuation of the trunk of the umbilical vein—through which some of the blood returning from the placenta, passes directly to the inferior vena cava, and to the right auricle of the heart, without traversing the liver.

The blood thus received from the inferior vena cava (being that from the body below the diaphragm), and also from the placenta, does not pass into the right ventricle. A very interesting piece of mechanism obstructs its passage in that direction, and favours its flow across the right auricle through the foramen ovale, now freely open in the septum, into the left auricle. This is the Eustachian valve, which is situated between the inferior vena cava and the right auriculo-ventricular opening, and being connected with the anterior and inferior part of the annulus ovalis, it brings the foramen ovale into very close connection with the inferior vena cava, and forms an imperfect septum towards the auriculo-ventricular opening, quite sufficient, however, to impede the flow of blood in the downward direction.

Arrived in the left auricle, the blood is transmitted thence to the left ventricle, and from this latter cavity through the arch of the aorta to the head, neck, and upper extremities, whence it is returned

by the venæ innominatæ and by the superior vena cava to the right auricle, which transmits it to the right ventricle. This latter ventricle propels it into the trunk of the pulmonary artery, which, in the fœtus, divides into three vessels, not into two, as in the adult. These are the two pulmonary arteries which separate from the trunk at right angles, one for each lung; and between them, following the direction of the parent trunk, a large vessel, nearly as large as the pulmonary artery itself, which forms a direct anastomosis with the aorta, just below its arch. This is the *ductus arteriosus*, through which the blood is transmitted directly from the right ventricle to the commencement of the abdominal aorta.

Of the Forces by which the Blood is circulated.—The principal force by which the blood is moved throughout the vascular system, and returned to the heart, is that which is generated by the contraction of the left ventricle, or what is commonly called the *vis a tergo* of the heart.

The force with which the heart propels the blood into the arterial system has been variously estimated. Valentin considers that the left ventricle exerts a force equal to one-fiftieth of the weight of the body; and, taking the muscular power of the right ventricle to be half that of the left, he would estimate the power of the latter at one-hundredth part of the weight of the body. This would give a force of upwards of three pounds for the left ventricle for a man weighing eleven stone, and half of that for the right.

Now Hales had long ago (1769) shown that, under the pressure of a column of water nine feet and a half in height, fluid might be made to pass from the carotid artery to the jugular vein through the capillary system. And it is well known to anatomists that, when the vessels are free from coagulated blood or other mechanical obstruction, thin fluids may be transmitted by a very slight force from the arteries to the veins.

Dr. Sharpey's experiments* indicate the exact amount of force necessary for this purpose. A syringe with a hæmadynamometer, to show the amount of pressure used, was adapted to the thoracic aorta of a dog just killed, the abdominal aorta having been previously tied immediately above the renal arteries, and the inferior vena cava opened just as it passes through the diaphragm. Fresh defibrinated bullock's blood was injected with a pressure of three and a half inches of mercury, and passed through the double capillary system of the intestines and the liver out of the veins with a full stream. When the pressure was increased to five inches, the blood spirted from the vein in a full jet. When the aorta was not tied above the renal arteries, the same pressure sufficed to drive the blood through the vessels of the lower extremities, and it was made to traverse the capillary system of the lungs, by a pressure of from one and a half to two inches of mercury, so as to flow freely through the pulmonary veins. Allowing one pound for every two inches of mercury,

* See Williams's Elements of Medicine, 3d Am. Ed. p. 154.

it would thus appear that a pressure of two pounds was sufficient to complete the circulation through the two abdominal capillary systems —and of one pound for the pulmonary circulation.

Unless, then, we assume that there are obstacles to the flow of blood through the vascular system, which, during life, are much greater than those after death, it must be granted that the heart's force, which in man does not probably exceed three pounds, is sufficient to drive the blood throughout the three systems of bloodvessels, and to maintain the current of the circulation; and that this force alone is capable of producing all the grand phenomena of the circulation.

It remains, then, to inquire whether the *vis a tergo* of the heart is the sole force by which the circulation is maintained, or whether we must not seek for the operation of other forces in order to explain its phenomena. To determine these points we must investigate the phenomena of the circulation in each of the systems of bloodvessels, and first in the arteries.

Phenomena of the Circulation in the Arteries.—By each contraction of the left ventricle a certain quantity of blood is pumped into the arterial system, which is already full. Were the arteries and other bloodvessels a series of rigid and inelastic tubes, there would necessarily ensue upon this a discharge of blood, corresponding in quantity and rapidity, from the opposite extremity of the system. It is plain, however, from the slow rate of the venous circulation, and the less capacity of the auricles as compared with the ventricles, that this does not take place in the vascular system; nor, considering the great extent of surface which the blood has to travel over in the capillaries, and the consequent friction it has to encounter, can it be expected that a quantity of blood should be discharged into the capillaries equal to that which the heart injects into the arteries.

Room is obtained for each fresh quantity of blood (beyond that which can be simultaneously expelled from the opposite extremity of the vascular system), by the dilatation of the arteries under the force of the heart. The eminently extensible and elastic character of the arterial walls thus gives a peculiar feature to the arterial circulation, and is turned to good account in maintaining the flow in that system of bloodvessels. In yielding under the force of the heart the arteries become dilated at each systole, to the extent, according to the experiment of Poiseuille upon the carotid of a horse, of one twenty-third of its diameter, or of one twenty-second, in a similar trial by Valentin on the carotid of a dog; but which must vary in different arteries and at different times with the force of the heart, and the extensibility of the arterial wall. Poiseuille's observation, however, pointed out unequivocally the fact (previously doubted), that the arteries are dilated at each systole of the heart.*

This dilatation of the arteries calls into play a force which in some degree replaces the heart's force. The elastic arterial wall, stretched

* See the account of Poiseuille's experiment, and a figure of his instrument in Magendie's Journal, tom. ix., and also in Valentin's Physiologie, Bd. i. p. 449.

by the contraction of the heart, reacts with a power which approximates more closely to that by which it was dilated according as the arterial tissue is more or less elastic. The arteries are thus made to contract upon their contained blood, and to drive it onwards or from the heart, and backwards or to the heart. Its course, in the latter direction, is speedily checked by the sudden and forcible closure of the aortic valves under the pressure of the regurgitating current. Therefore, the great mass of the blood rushes onwards towards the capillary system—propelled first by the heart's impulse, and, secondly, by the elastic reaction of the arterial walls.

This elastic reaction of the parietes of the arteries does not come into play until the heart has ceased to contract and begun to dilate. It is, therefore, synchronous with the diastole of the heart, and corresponds with it in duration; so that, while the ventricle is inactive, the blood in the arteries is still being pressed upon by the reacting arterial walls. Thus the blood is ever moving onwards throughout the arterial system, during the diastole, as well as during the systole of the heart; and the jerking impulses communicated to it by the successive contractions of the ventricle, are gradually converted into that continuous uniform forward movement, which is observed under ordinary circumstances in the ultimate arterial ramifications, the capillaries, and the veins.

An analogous application of the reacting force of an elastic agent to convert a jerking movement into a continuous stream is found in the mechanism of the fire-engine, and of the organ. In the one, water, in the other, air, is forced into a chamber in which air already exists. This air undergoes compression by the sudden introduction of a new quantity of water or air. Its elasticity causes it to react, and thus to supply an expulsive force during the subsidence of the action of the piston in the one case, and of the bellows in the other.*

The heart, by its propulsion of blood into the arterial system, not only dilates the arteries, but elongates them likewise. This is generally better seen than their dilatation, but it is most apparent in arteries which are curved. Under the influence of the heart's systole the curves are distinctly altered, so as to form segments of larger

* This explanation of the influence of the elastic reaction of the arterial walls in promoting a continuous stream, and converting the jerking current of the blood in the large arteries into a uniform one in the small ones, is very commonly attributed by modern writers, to Weber. English physiologists ought not to have overlooked John Hunter's remarks (on the Blood, &c. 4to ed. p. 129), nor Sir C. Bell's observations in his Animal Mechanics, p. 44. But the following passage from Hales will show that that able observer held much the same views long prior to either of the last named. * * * "The blood in the arteries," he says, "being forcibly propelled forward, with an accelerated impetus, thereby dilates the canal of the arteries, which begin again to contract at the instant the systole ceases; by which curious artifice of nature, the blood is carred on in the finer capillaries, with an almost even tenor of velocity, in the same manner as the spouting water of some fire-engines is contrived to flow with a more even velocity, notwithstanding the alternate *systoles* and *diastoles* of the rising and falling *embolus*, or force; and this, by the means of a large inverted globe, wherein the compressed air alternately dilating or contracting, in conformity to the workings to and fro of the embolus, and thereby impelling the water more equally than the *embolus* alone would do, pushes it out in a more nearly equal spout."—*Hydrostaticks*, p. 22, § 26.

circles, a motion is communicated to the artery, and a change of place results; and straight arteries, which are more or less confined by the superjacent parts, become slightly curved under the same force. Thus, in the course of time, the arteries, especially those of parts to which by reason of a more active nutrition in them there is a considerable afflux of blood, assume a tortuous form, as may be seen in the temporal and radial arteries of old persons, and in the spermatic artery of the bull.

The Pulse.—When the finger is applied to an artery during life, it is felt to beat or pulsate in correspondence with the systolic actions of the heart, so that the number of pulsations in the artery corresponds exactly with the number of beats of the heart, and, if an occasional interruption in the heart's action takes place, or what is called an intermission, there will be at the same time a failure in the beats in the artery.

This phenomenon is called the *pulse*. From their contiguity to the heart, it is always present in arteries; but it may occur in veins under circumstances to be explained hereafter. It is due to the same cause which occasions the blood to flow *per saltum*, or by successive jets, from a divided artery. That cause arises out of the manner in which blood is pumped into the arterial system by successive jerks. Each jet of blood creates a wave which moves along the whole arterial system. The same phenomenon may be observed, if water be injected by successive jerks into a narrow channel already full or nearly full, and open on the surface. Each fresh jet will create on the surface of the water in the channel a wave, which may be followed to its most distant extremity. This wave, even in a rigid tube, if sufficiently forcible, would communicate to the wall of the tube a thrill or vibration indicating the course which the wave takes. But in an elastic tube which yields under the injecting force, the phenomenon is more distinctly perceived as the tube dilates under the pressure of the advancing wave.

It is important to notice that the phenomenon of the pulse in arteries is due solely to the wave excited by each successive injection of blood into the arterial system from the heart. The walls of the arteries have nothing to do with the causation of the pulse, but may render it more or less distinct according as they are more or less yielding.

The character or quality of the pulse will depend primarily and essentially upon the force of the heart—secondly, upon the integrity of the mechanism by which that force is directed so as to drive the blood into the arteries—thirdly, upon the quantity of blood in the vascular system—and, fourthly, upon the condition of the arterial wall, according as it is apt to oppose or to yield before the wave caused by the heart's action. By reference to these points, we may explain the various conditions of the pulse observed in practice. Thus a weak heart, or a contracted arterial aperture, or a small supply of blood, will each equally produce a small pulse; while a certain power of heart, and an open unimpeded state of the arterial aperture, with a full supply of blood, are quite necessary to the

formation of a large round pulse. But the qualities of softness or fulness, of hardness or wiryness, of compressibility, of incompressibility, all which are familiar to the *tactus expertus* of the practical man, are determined by the yielding or the resisting condition of the arterial wall.

Contractility of Arteries.—Arteries possess a power of contraction in virtue of the large quantity of elastic material which enters into the constitution of their wall; but this is a contraction which may occur in a dead as well as in a living artery, and which simply serves to restore to its medium dimensions an artery previously distended or stretched. They have, however, also a power of active contractility, which ceases with life, which is capable of being called into play not only by distension, but by other appropriate stimuli, and which can diminish the size of the vessels far beyond what their mere elasticity could effect, and even against the influence of the elastic force. This contractile power is due to the presence of unstriped muscular fibres in the arterial wall. The demonstration of these fibres in the walls of arteries by the microscope leaves no more doubt of the existence of a muscular contractile force in them than of its existence in the œsophagus or the intestine. Experiment anticipated anatomical research in pointing out that arteries contract as tubes do whose walls contain muscle, and it also indicated the peculiar manner in which the muscular fibres of arteries act. Under the influence of a stimulus even of so slight a nature as exposure to the air, an artery may be observed to contract very gradually, and to become very much diminished in size. Thus, in one of Hunter's experiments, the posterior tibial artery of a dog was laid bare; it was observed, in a short time, to be so much contracted, "as almost to prevent the blood from passing through it, and when divided the blood only oozed out from the orifice."*

Mechanical stimulation, applied to a living artery, such as gentle friction with the point of a scalpel or needle, excites in its wall a slow and gradual contraction at the point stimulated, so that it appears constricted at that point. We have, by stimulating an artery in this way, at several points at some distance from each other, produced quite a moniliform appearance of it, causing a series of constrictions separated by portions in which the size of the artery was little altered. Verschuir was among the first to observe the effects of mechanical stimulation upon arteries, and he has recorded the results of his observations in his Inaugural Dissertation *De Arteriarum et Venarum vi irritabili*, published in 1766; and numerous experiments of a similar kind were performed in this country by our friend, Dr., now Sir Charles Hastings, which are detailed in his treatise on *Inflammation of the Mucous Membrane of the Lungs*, published in 1820.

The galvanic stimulus is also capable of producing contractions in arteries, but it requires to be repeatedly renewed before the effect is manifest. The most striking results from the application of this

* Hunter on the Blood, &c. 4to. ed. p. 114.

nd of stimulus, were obtained by the Webers, in their experiments ith the rotatory magneto-electric instrument. The shocks were plied to the small mesenteric arteries of frogs, and a diminution their diameter to one-third was produced, in from four to ten conds; and the contraction increased under the continuance of the imulus, until the caliber of the vessel became from three to six mes smaller than at first, so that only a single row of blood-cor-uscles could pass through it; at length the vessel became completely losed, and the circulation through it stopped.

From the combined evidence of anatomy and experiments, then, can no longer be doubted that arteries possess an inherent con-actility, in virtue of the presence of unstriped muscular fibres in eir tunics. It remains to inquire, in what manner this power fluences the circulation in the arterial system. Does it help to ropel the blood? This question may be answered in the negative. he manner in which arterial trunks taper towards their distal tremities, renders it mechanically impossible that the contraction circular muscular fibres around them would drive the blood on-ards unless some valvular apparatus checked its passage backwards towards the heart. It is by reason of the existence of such an paratus at the mouth of the aorta that the elastic coat of the teries by its reaction propels the blood. But the muscular coat ould not contract simultaneously at all points as the elastic coat es. It would, as in the œsophagus and intestines, act in successive rtions—and the artery would, as in those tubes, be almost or al-gether obliterated at the point of contraction. It is easy, however, show that no such vermicular action takes place in the arteries, r can it occur in tubes which, like them, are always and at all ints filled.

It seems most probable that the contractile power of the arteries ercises a regulating influence upon the flow of blood through them. s influence in this respect has long been recognized by practical en, under the name of *tone* or *tonic power*. It restrains within e bounds the distension of the arteries, limits the quantity of blood each artery, adapts the size of the artery to the volume of its ntents, and offers a certain amount of opposition or antagonism to e force of the heart.

It is owing to the resistance afforded by this contractile power arteries to the passage of fluid into them, that the anatomist will il to inject a tissue completely, if he attempt it too soon after ath. The well known experiment of John Hunter, on the pla-nta, shows how long the contractile power will remain in the teries of a part after its separation from the system, or after ath. In a woman delivered on Thursday, the navel-string was parated from the fœtus in the usual way, by tying the cord in o places, and dividing it between them—thus the blood was re-ined in the vessels of the cord and placenta. On the Friday orning, a ligature was placed an inch below the lowest of those gatures, and that inch was cut off. The blood immediately gushed ut, and, on watching the cut ends of the vessels, Hunter observed

the arteries contracting with the whole of their elastic power, which took place immediately. The next morning (Saturday), on examining the mouths of these arteries, they were found quite closed up, so that in twenty-four hours the muscular coat had contracted to such a degree as to close up the area of the artery. On Saturday morning the experiment of Friday was repeated with another inch of the cord, with precisely the same results, but after its repetition on the Sunday, it was found on the Monday that the mouths of the arteries remained open, their muscular coat having by that time lost its contractility.*

The difference in the results obtained by Hales, as regards the velocity with which certain fluids passed through the bloodvessels, is referable to the contractile power of the arteries. Thus, while warm water, injected into the bloodvessel of a dog's bowels, passed in fifty-two seconds, the same quantity of common brandy took sixty-eight seconds; cold water (fourteen degrees above freezing) was eighty seconds longer in passing than the same quantity of warm water just before. A strong decoction of bark took much longer to pass through the vessels than the same quantity of warm water. Sixteen pots, of equally warm decoction of bark, were successively poured in, the first of which passed in seventy-two seconds; the sixteenth, "as the vessels grew more and more contracted by the styptic quality of the decoction," was 224 seconds in passing.†

This contractile power in the walls of arteries (their *tone* or *passive contraction*) is capable of modifying considerably the character of the pulse. When it is feeble, the artery offers but slight resistance to the entrance of the blood, and it therefore yields more completely under the force of the heart. Hence, fulness of pulse and feebleness of muscular power of *tone* in the wall of the artery, are apt to go together. On the other hand, an exalted muscular power or *tone* in the wall of the artery, by contracting the arterial tube, and resisting the flow of blood, would cause a *small*, *hard*, and even a *wiry* pulse; or a similar effect might be produced by an irritating fluid, as a diseased blood, passing through the artery. Again, failure of the tonic property of the arterial wall causes a *compressible* pulse; an excited or well-developed tonic power, will case an *incompressible* pulse.

Of the Force of the Heart.—The blood encounters considerable obstacles to its passage through the vascular system, which tend to bring it to a state of rest. The friction against the inner surface of the vessels, and the resistance of the elastic and muscular elements of their walls to distension, must be overcome by any force capable of keeping up a continual renewal of the supply of blood to the several organs. Moreover, a certain rate of movement must be maintained in the blood's current. The attainment of these objects is clearly

* Hunter, *loc. cit.* p. 116. The muscular fibres of the arteries of a part recently dead pass into the state of *rigor mortis*, like that of other muscles, which will last a certain time: the proper period for anatomical injections is either *before* the rigor mortis has come on, or *after* it has ceased.

† Hæmastaticks, p. 124, *et seq.*

ided for, in the main, by the action of the heart, and that living p is doubtless endowed with energies sufficient to drive into bloodvessels renewed supplies of blood, with a force and a velo- exactly adapted to overcome such natural obstacles as the action ie vascular system must naturally create.

) estimate the force of the heart, we must ascertain the pressure h the blood exercises on the walls of the bloodvessels during and we must measure the rate at which it flows through them.

fluid flowing through a tube exerts a double force, one in the tion of the long axis of the tube, *the force of the stream*, of h the velocity gives a measure, and another, which is the pres- of the fluid against the wall of the containing tube or *the lateral ure.* This latter force is always proportionate to the resistances h the fluid has to encounter to its flow. The longer the tube, igh which the fluid passes, the rougher its walls, the narrower opening through which it escapes; and the more glutinous the , the greater the lateral pressure.*

tube fixed into the walls of the tube through which the fluid , and at right angles to it, affords a simple means of measuring ateral pressure, by the height to which the fluid will rise in it. qually simple means we may measure both forces, if the measuring be prolonged into the other tube with its orifice opposite to the m. The height which the column of fluid will attain in a tube rranged, will indicate the altitude from which it must have n, to acquire the velocity and force with which it streams igh the main tube.

tot, a distinguished French engineer, who lived about the le of the last century, employed a tube of this kind for mea- g the velocity of the stream in rivers. The tube was bent at ht angle, into two unequal branches, and the smaller or hori- al branch was immersed in the stream with its mouth opposed . The height of the column sustained in the tube afforded a ure of the force and velocity of the stream, that height being as the water must have fallen from, in order to have acquired ame velocity.

ales adopted a similar method to measure the pressure of the l in the arteries. He inserted into the left crural artery of a , a brass pipe, whose bore was one-sixth of an inch in diameter; to that, by means of another brass pipe, he fixed a glass tube arly the same diameter, which was nine feet in length. When lood was allowed to flow into this tube it rose in it to a height t feet three inches above the level of the left ventricle of the t. After considerable loss of blood, however, the power of taining a column of this height ceased, and the blood rose, after uccessive bleedings to seven, six, five, four, and at length, to two four inches.

a second experiment, exactly the same, excepting that it was e on a horse of more vigour than the subject of the previous one,

See Volkmann, die Hæmodynamik nach Versuchen. Cap. i. Leipzig, 1850.

the blood rose to nine feet eight inches, and fell subsequently, after successive bleedings, in the same manner as in the first experiment. A third experiment made upon a mare, consisted in fixing the brass pipe into the carotid artery towards the heart, and to that the wind-pipe of a goose, on account of its pliancy, and to the other end of that a glass tube, twelve feet nine inches long. The blood rose in the tube to nine feet six inches, and behaved, in all respects, much in the same way as in the former experiments. And afterwards, Hales experimented in the same way on the sheep, the deer, the dog, with results essentially similar, but varying with the size and general power of the animal.

Hales estimated the force of the left ventricle of the heart at the moment of its systole, by multiplying the area of its inner surface into the height of the column of blood in the tube which it was capable of sustaining, calculating also the absolute weight of the quantity of blood which formed that column. From these data he concluded that the contraction of the left ventricle of the horse's heart was capable of sustaining a weight of 113 lbs., that of the sheep 36.56 lbs., that of the dog 33.61 lbs., when the animal weighed 52 lbs., and 19.8 and 11.1 lbs. in dogs weighing respectively twenty-four and eighteen pounds.

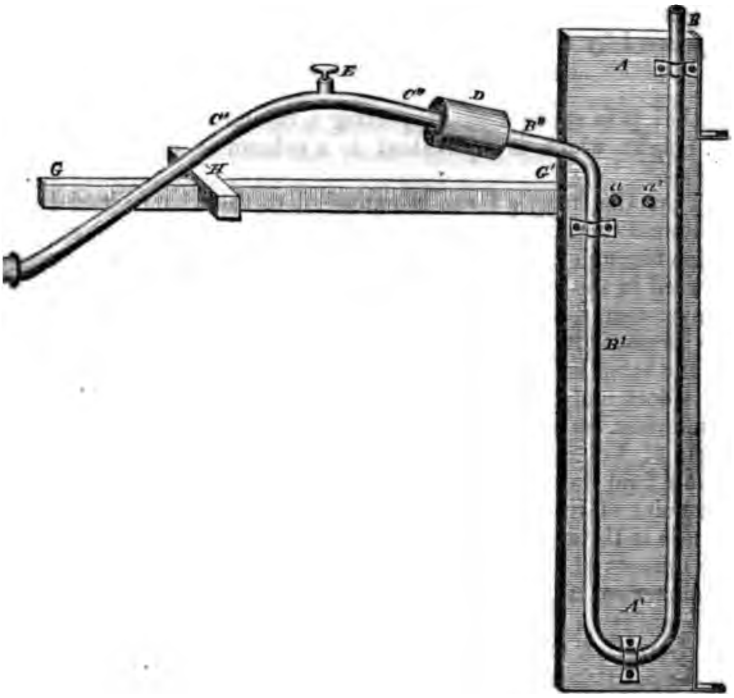
Poiseuille improved upon the method of Hales's experiments, and obviated some objections to them. He employed an instrument which he called *the hæmadynamometer*. (Fig. 201.) This consisted of a glass tube bent so as to form a horizontal (B″) and two perpendicular (BB′) portions. The horizontal portion is capable of being adapted by means of brass tubes of various size to arteries or veins, however different in caliber. The tube is attached to a board (AA′), on which a scale is marked. To use it, mercury is poured into the perpendicular branches of the tube, and will, of course, stand at the same height in each when the instrument is kept in the perpendicular.

In order to prevent the coagulation of the blood, which, by causing it to adhere to the sides of the tube, would complicate the experiment (a point not provided against in Hales's experiments), a quantity of a strong solution of carbonate of soda is poured into the horizontal branch, and will therefore rest upon the column of mercury in the nearest vertical branch.

The instrument is now adapted by means of a pipe provided with a stopcock (F) to the artery in which the blood is to be measured. On opening the stopcock the blood rushes into the horizontal tube, mingles with the alkaline solution, and pushes down the mercury in the vertical tube B′, that in the tube B rising to the same extent as the first is depressed. The rise and fall of the mercury in each vertical branch can be measured on scales placed behind them, and as the rise and fall are equal, the double of either will give the height of a column of mercury which the force of the stream of blood is able to maintain. By causing the blood to press upon a column of mercury, Poiseuille got rid of the necessity of having a very long tube as used by Hales.

iles inferred, from his observations on the lower animals, and a parison of the measurements of their arteries with those of man,

Fig. 201.



uille's hæmadynamometer as slightly modified by Volkmann: AA' the board to which the bent glass B'B'') is attached. CC'C'' a tin tube which is fixed through a cork (D) air-tight to the horizontal of the glass tube. E an opening with a stopcock in this tube. F a conical tube which may be ced into an artery or vein. This is provided with a stopcock which serves to regulate the admis- the blood into the tube of the hæmadynamometer. G H G' an arm of wood connected with the which serves to support the tin tube, and so protect the horizontal branch of the glass tube.

the force of the heart in the human subject is capable of sus- ng in a tube fixed in the carotid artery a column of blood 7½ high, and calculating the surface of the left ventricle at 15 re inches, he concludes that, when it first begins to contract, the ricle supports a pressure of 51.5 lbs. of blood. And Poiseuille ns 4 lbs. 4 oz. as indicating the force which the left ventricle s at the moment of its contraction in propelling the blood into orta.

lkmann combats the grounds upon which Poiseuille's calculation formed; and assigns the heart's power as equivalent to the force h sets the stream of blood in motion, and gives it its proper ve- y, and also to that which enables it to overcome the obstacles it o encounter. This latter power is determined by the pressure e artery, which is found in the mean, in the carotid artery of mals, to be capable of supporting a column of mercury of 200 metres, or about 7 inches; or a column of blood of 2700 milli-

metres (mercury being 13.5 times heavier than blood); whilst the former force, taking the actual velocity of the blood in the commencement of the aorta at 400, and in the carotid at 300, would be represented by a column of blood a little more than 8 millimetres in height. Thus it would appear that the force of the heart may be expressed by the following formula:—

$$H = 8.2 + 2700 \text{ millim.}$$

or that it is capable of supporting a column of blood nearly 9 feet in height, which is equivalent to a column of mercury of about 8 inches.*

That the heart's force is extended to the whole arterial system, and must therefore be highly instrumental in maintaining the circulation through it, is shown by the fact that a considerable pressure is exerted in the various arteries, which can be measured by the hæmadynamometer, or by other instruments. Poiseuille had affirmed that the pressure in all the arteries was the same, a column of mercury of the same height being supported by the blood's pressure in all.† This doctrine, however, is at variance with every obvious hydrodynamic fact, as also with the results of other observations, of which those of Volkmann seem the most trustworthy. Volkmann shows that a fluid flowing through a system of tubes has to encounter at the point of its entrance into it the sum of the resistances which oppose it throughout the entire area, and these resistances determine the amount of pressure needed for its propulsion. Applying this to the arteries, it is plain that in them the blood has to encounter the resistances in the capillaries, in the small arteries, in the middle-sized arteries, and in the arterial trunks—a fact, which, by assigning to the resistance in each of these regions the symbols x, y, z, w, z representing that in the arterial trunks, and the other letters that in each of the remaining segments of the system, may be thus expressed, P (being the pressure in the commencement of the arterial tree) $= x + y + z + w$, whence it is plain that the amount of pressure cannot be the same in all parts of the arterial system, but diminishes steadily as the artery is more distant from the heart.

Spengler's experiments so far disprove the accuracy of Poiseuille's statement as to show that the pressure of the blood differs considerably in different arteries; but in the greater number of his observations the pressure appeared to be greater in the arteries more distant from the heart, some showing a difference of 36 millimetres in favour of the more distant artery; but in one of the instances quoted by Volkmann from Spengler, there was a difference of 16.6 millimetres in favour of the carotid artery as compared with the maxillary.

* See the remarks on this subject in the late Dr. Young's Croonian Lecture on the Functions of the Heart and Arteries. Phil. Transl. 1809, and republished in his Introduction to Med. Literature, 1823, p. 607, *et seq.*

† As an example, the pressure in the carotid of a dog, distant 208 millim. from the heart, and that in the humeral artery 303 millim. distant, support a column of mercury of 179.04 millimetres. Whence Poiseuille infers that a particle of blood in the carotid, distant from the heart 208 millim., moves with the same force as a particle in the humeral artery, which has a distance of 303 millim.

But Volkmann's very numerous observations, made with more perfect instruments than those used by Spengler, show a marked difference of pressure in the near and in the distant arteries. Thus, eight observations on the carotid, and a branch of the femoral artery of a large dog, gave a mean of 7.2 millimetres (0.27 inch) in favour of the carotid. And ten observations on the carotid and metatarsal arteries of a calf yielded a mean of 27 millimetres (1.05 inch) in favour of the carotid; and twelve observations on the same arteries of another calf gave a mean of 19.5 millimetres also in favour of the carotid. Volkmann has also shown that, in the same artery, a notably greater pressure exists in the part near the heart, than in that more remote from it, which is, of course, the more conspicuous, as the distance between the two points measured is greater.

Influence of Systole and Diastole.—Hales had observed, in his experiments with a simple glass tube, that a rise and fall took place in the column of blood to a variable extent at and after each pulse. This observation has been confirmed by Ludwig, and also by Volkmann. The rise corresponds to the heart's systole, the fall to the diastole. This affords, in the greatest part of the arterial system, the clearest proof of the extension of the heart's influence throughout it. And Poiseuille showed that the pulsations of the heart could be counted by noticing the advance of the blood in pulses along the capillaries, and, under certain circumstances, even along the small veins.

Influence of Respiration.—That respiration exercises an influence upon the circulation has been likewise noticed by several observers. Hales had referred to this; he had noticed how the straining efforts of the animals which were made the subjects of his experiments, were followed by a rise of the column of blood in the tube, and how the same effect followed deep sighing. And Poiseuille found that during expiration the height of the column of mercury was much increased, but that it fell in inspiration. In forced and deep inspirations the force of the heart becomes so much diminished in some cases that no pulse, or at most a very feeble one, can be felt at the wrist: on the other hand, in forcible expirations the pressure of the blood in the arteries becomes double its normal amount. This has been farther confirmed by Ludwig and Volkmann. The fact is of practical interest, and affords good reasons why the practitioner should caution those whose arteries are weakened by a diseased state of their tunics, against strong efforts, or against any action likely to disturb the quiet and freedom of the breathing.

The heart's force is materially weakened, as Blake's experiments show, by the introduction into the circulation of poisonous agents of a sedative nature. And there is every reason to believe that the existence of particular animal poisons in the blood, as the typhus poison, that of scarlet fever, of erysipelas, &c., is capable of depressing the heart and weakening the circulation.

Thus, then, as far as regards the powers by which the blood is moved in the arteries, it may be stated that the circulation is maintained in them by the force of the heart; replaced and propagated

throughout the system by the elastic reaction of the arterial tunic, and to a certain extent restrained or modified by the muscular contraction of the same tunic, which likewise serves very accurately to adapt the size of the arteries to the quantity of blood contained in them.

On the Velocity with which the Blood moves in the Arteries.—The calculations of Hales and others on this subject, led to ideas respecting the velocity of the blood, which appear to be extravagant. Thus Hales inferred the velocity of the blood at the commencement of the aorta in man, to be at the rate of 735 feet in a second! The data upon which these calculations were founded are uncertain and unsatisfactory, such as the measurement of the area of the aorta at its origin, and the capacity of the ventricle and the quantity of blood expelled by each systole.

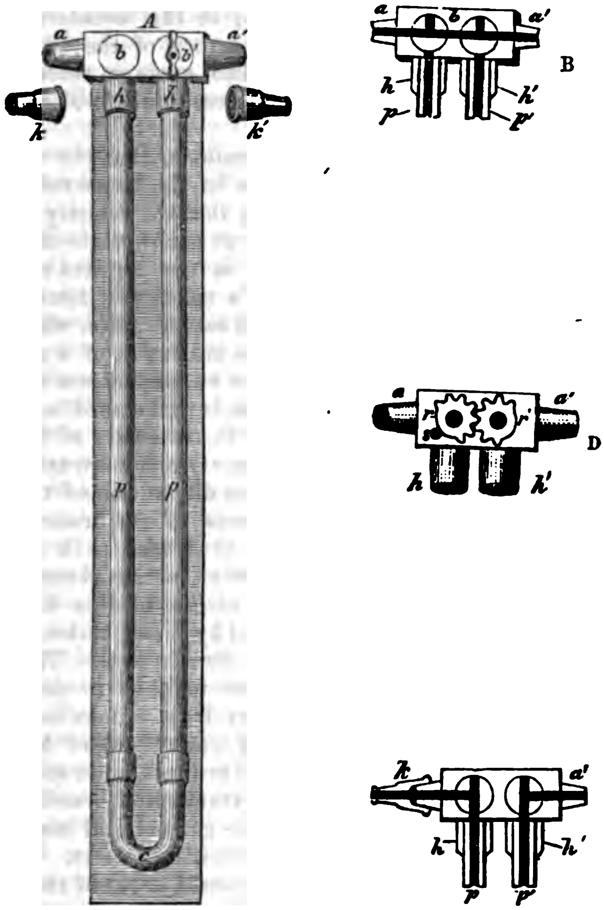
Volkmann has lately devised an instrument for the direct admeasurement of the rate of the blood's movement in the arteries. He calls it the *hæmodromometer.* It consists of a glass tube, containing water, 52 inches long, bent into the form of a hair-pin, which is substituted for a segment of the bloodvessel, in which it is required to measure the velocity of the blood's stream. The column of blood which comes from the heart pushes the column of water before it, without any great mixture of the two fluids taking place, and in passing through a determined space it takes a measurable time, whence it may be calculated how far the blood moves in a second.

The following description will explain the instrument and the mode of using it. At A (Fig. 202) is a metal tube, an inch and a half in length; the ends of this (a, a') are conical, and fit into two corresponding conical tubes (k, k'), made like the pipes of an injecting syringe, so that they can be readily fitted into an artery. A stopcock (b') commands the channel of this tube, not only at a' but also, by two cogged wheels, at a. The mechanism of this arrangement may be readily understood, by reference to the adjoining sections of this portion of the instrument and B and C, and the view of its other surface at D (r, r' D). At h, h' are two short tubes, also of metal, which are fitted into the horizontal tube below the stopcock, and so that their channels (as shown at C) may communicate with, and be exactly equal to, that of the horizontal tube. The stopcock (b') commands this communication likewise. These short tubes (h, h') fit exactly upon the bent glass tube (p, p), and complete the communication between its channel, and that of the horizontal tube at its extremities. When the stopcock is turned so as to open the channel of the horizontal tube throughout, as at B, all communication with the glass tube is cut off; on the other hand, when the communication with the glass tube is opened, as at C, the channel of the horizontal tube is stopped, and fluid entering at a', would have to pass through h', and to traverse both limbs of the glass tube (p, p) emerging at a. For the protection of the instrument in using it, the glass tube is attached to a board, to which is fixed a scale marked in metal.

In order, then, to use the instrument, a large artery is freely ex-

posed for not less than three inches, and, after due precaution has been taken to counteract hemorrhage, it is divided by cutting out a piece; the conical pipes (k, k') are then fixed into the open ends

Fig. 202.



of the artery, one being directed towards the heart, the other towards the capillaries. They must be fixed far enough apart to admit of the introduction of the horizontal tube (A) between them, without altering the usual direction of the arterial stream. When this tube is fitted to the conical pipes, then the bent glass tube, previously filled with water, must be fixed to it by means of the short tubes (h, h', C), the stopcock being so turned as to shut off all communication with the glass tube. As soon as the instrument has been properly fixed in the artery, the blood is allowed to flow into the glass tube. It may be now seen to traverse the glass tube with a velocity very nearly the same as it has in the artery, and in doing so it pushes the water before it into the peripheral bloodvessels, with

(according to Volkmann) only a very slight admixture between the two fluids.

By trials made with his hæmodromometer, Volkmann found, in the case of seven dogs, that the blood flowed in their carotids with a velocity ranging between 205 and 357 millimetres in a second; in that of horses, 306 to 234; in the metatarsal artery of the horse, 56, and in the maxillary artery of the same animal 99; in the carotid of a calf, 431. The average velocity in the carotids of mammals is stated by Volkmann to be 300* millimetres in a second.

It results, likewise, from these observations, that the velocity of the blood in the large arteries, and also in the large veins, is considerably greater than in the capillaries; that the velocity in arteries is not uniform, but is suddenly increased at each systole of the heart, and that the blood moves most quickly in the arteries nearest the heart. It appears, also, that the blood's velocity is materially lessened by loss of blood, and that increased rate of pulse, which always follows considerable losses of blood, is no indication of a more rapid blood-current, but, on the contrary, often accompanies a retardation of it. The velocity of the blood-current is influenced not so much by the rate of action of the heart, as by the intensity of its systole, and the quantity of blood which it expels at each contraction.

Much was formerly said respecting the disposition of the arterial tree, being such that the combined areas of the branches of an artery exceeded that of the trunk, and that with each succeeding series of subdivisions, the blood flows into an increased area. Haller (tom. i. p. 77) ascribes the first observation of this kind to an Englishman named Cole.†. It is repeated by Keill, Hales, and many others, among them John Hunter and Sir C. Bell. The general effect of such an arrangement would obviously be to diminish the rate of movement of the blood as it flows from trunks to branches. But the careful measurements of Mr. Fernaby and of Mr. Paget, render it necessary to modify the general proposition to some extent.

Mr. Fernaby‡ compared the areas of trunks and branches in the only sound way, namely, according to the geometrical law, that the *areas* of circles are as the *squares* of their diameters. Estimated thus, he found that the excess of the combined areas of the branches over those of the trunks was very trifling, and, in some instances, scarcely appreciable; and Mr. Paget, while confirming the general statement of Mr. Fernaby, discovered a remarkable exception in the case of the common iliac arteries, whose combined areas were distinctly less than that of the aorta above the point of bifurcation—and the combined areas of the external and internal iliacs were less than that of the common; but those of the branches of the external iliac exceeded notably the area of their parent trunk.§

Volkmann states that, in general, the arterial capacity is increased

* Tolerably close approximations to the value of these measurements in English inches, may be obtained by dividing each number by 25.

† De Secretione animali. Oxon. 1674.

‡ Lond. Med. Gaz. 1839.

§ Lond. Med. Gaz. 1842.

in area by the division into branches. But he instances a remarkable exception in the case of the external and internal carotids of the horse, whose combined areas are smaller than that of the trunk. He remarks, likewise, that the first divisions of the larger arterial trunks (aorta and pulmonary artery) experienced very little increase of area; but that, as subdivision goes on, the increase becomes much more marked. And it is especially so near the capillaries, where the combined areas of some small branches nearly double that of their parent. This is particularly interesting, as denoting the coincidence of physical conformation with the result of direct observation, on the velocity of the blood, which show that it is near the capillaries that the most decided diminution takes place in the rate of the blood's motion.

Of the Circulation in the Capillaries.—The manner in which the blood flows through the capillaries is easily made the subject of direct observation by examining the transparent parts of certain animals, as the wings of bats, the mesenteries of small animals as the mouse, the web of the frog's foot, the lung of the frog, or of the newt, &c.

In watching the circulation in the web of the frog's foot under the microscope, with a magnifying power of about 200 diameters, the following points will attract observation; first, it will be seen that the stream is continuous, that is, it rushes with a considerable velocity, which is uniform when not affected by any extraneous influence; the course and rate of the stream are indicated by blood-particles which are carried along in it, and which seem to chase each other through the various channels and among the little islands of the solid particles of the tissue which the blood is destined to nourish. These particles most frequently pass in a single row, with a variable interval between them; sometimes, however, they seem to rush in pairs, or in threes, according to the size of the capillary channels through which they flow. Secondly, it will be noticed that the greatest velocity of the stream is in its centre, a fact which comports with what is observed in rivers and other channels through which water flows, while towards the circumference the stream becomes much slower, so that the layer of fluid which is in immediate contact with the capillary wall is almost or completely still. The particles are carried along in the centre or rapid part of the stream, and but occasionally a solitary particle seems attracted towards the circumference. This is most frequently a colourless corpuscle, so that sometimes several colourless corpuscles are seen at intervals in contact with the wall of the capillary, as if drawn to it by some special attractive force, or moving much more slowly around the central mass of red particles. The sudden change from a rapid to a slow movement, or to perfect stillness, when one of these particles is thus drawn from the centre to the circumference of the stream, serves to display, in a very satisfactory manner, the peculiar feature of this portion of the contents of the capillary, which, from its apparent stillness and from the paucity of blood-particles in it, has been called the *still layer* of the *liquor sanguinis*. The existence of this still layer is doubtless a purely physical phenomenon, identical with that which is known to take place

when fluids pass through inorganic capillary tubes, in which the circumferential layer seems to adhere or to be attracted to the wall of the tube, and it would clearly favour the transmission of nutrient or other material dissolved in the liquor sanguinis, through the wall of the vessel, in obedience to a force of attraction between the blood and the tissue. This still layer forms but a small portion of the whole capillary stream—perhaps about one-eighth or one-tenth its breadth; it is greater when the circulation is slower; it is also broader, and therefore more visible, when a vessel makes a bend. The application of cold to the capillaries increases the breadth of this layer, whilst heat produces an opposite change.

The capillary vessels dilate or contract, under particular circumstances. Their dilatation is passive, and due either to an increased pressure of the blood into them, or to their distension under the same pressure in consequence of diminished tone of their wall. Their contraction is caused either by an inherent contractile power in them, or by the diminution of their contents in consequence of the contraction of the capillary arteries, in which latter case diminished pressure permits them to contract, in virtue of the *elasticity* of their walls. This latter would be the more probable view, in default of any proved existence of a muscular structure in the walls of the true capillaries, but there is no good reason why the nuclei observed in them should not be regarded as belonging to muscular tissue here in a membranous rather than a fibrous form.

The rate at which the blood moves in the capillary circulation has been made the subject of direct observation by various physiologists. It is slower than in the smallest veins, and still more so than in the smallest arteries. Hales had stated the rate of the circulation in the capillaries of the muscles of a frog to be an inch in a minute and a half, and in the pulmonary capillaries five times that velocity. Subsequent observers, Weber, Valentin, and Volkmann, give a somewhat greater velocity; Weber and Valentin make it about an inch and three quarters in a minute, and Volkmann found it about the same in cold-blooded animals, but twice as much in the capillaries of the mesentery of a young dog. These estimates are probably rather below the real rate of motion of the blood in the capillaries, if we allow for the degree of pressure and constraint to which they must be subjected in making the observations.

Of the Forces which maintain the Capillary Circulation.—The principal force by which the circulation is supported in the capillary system, is the *vis a tergo* of the heart. We have already adduced sufficient evidence to prove that that force is capable of driving the blood throughout the whole circulating system. The following facts may be stated in proof of this doctrine.

1. The pressure of the blood may be measured in the *veins*, in the same way as in the arteries, and this varies with the force of the heart. If, then, the heart's force extends to the veins it must do so through the capillaries.

2. The capillary and venous circulation in any segment of the body, is greatly influenced by the circulation in the main artery of

hat segment. Thus, Magendie found the circulation much retarded n the femoral vein by stoppage of that in the corresponding artery; nd by the hæmadynamometer it may be shown that the force of the lood in the veins diminishes or increases with that in the corresponding artery under certain circumstances.

3. In Fishes, the whole blood ejected from the heart passes, from he bulbus aortæ, through the branchial capillaries, before it enters he systemic vessel; thus illustrating how the heart's force may be ropagated through a complex network of minute capillaries, to oth arteries and veins, as well as to the system of capillaries which ntervenes between them.

4. In debilitated animals, it is evident, from the jerking movement of the blood in the capillaries, corresponding with the action f the heart, that the impulse of that organ is extended to these essels, unbroken by the elastic reaction of the muscular contraction f the arteries. This may be well seen in watching the circulation n the frog's web, or in the tale of the tadpole.

Thus, there can be no doubt that the heart's force is not only fully dequate to, but is the principal agent in, the maintenance of the apillary circulation. When this force fails, the circulation in the apillaries suffer as much as, if not more than, that in any other ortion of the vascular system; and the sluggish transmission of the lood through the capillaries, such as we often find when the heart s simply weakened, occasions congestions, particularly of dependent arts, and then, by the filtration of the serous portion of the blood hrough the parietes of the vessels, œdema and anasarca.

But however readily we may concede that the heart's action is he *principal* force, it must be confessed there are certain phenomena which do not admit of satisfactory explanation, on the supposition hat it is the only one employed in the maintenance of the capillary irculation; and it seems more reasonable to assume the influence nd exercise of some other force superadded to this, in order to xplain various phenomena which take place in, or which are dependent on, the circulation through the capillaries.

The more remarkable of these phenomena are blushing, or, in more general terms, the influence of mental emotion upon the capillary circulation; the influence of local irritation, whether accidental r morbid; and the effects of asphyxia.

It seems highly probable that in the ordinary molecular changes which take place in the nutrition of the tissues, a force is generated, which, in its normal state, must promote, by an attractive influence, he flow of blood through the capillaries. The cessation of such a orce would operate unfavourably to the flow of blood through the apillary system, whilst its existence in greater power at one point han at another, would cause a greater afflux of blood in the former han in the latter direction.

The best illustration of the exercise of this force, which, for the ake of brevity, may be designated *the capillary force*,* is found in

* The name *Capillary* force, which was given by Dr. Carpenter, must be taken as

the circulation of the sap in plants. It is exercised in two situations—at the roots and in the leaves—constituting in the one a *vis a tergo*, and in the other a *vis a fronte*. At the roots, a rapid imbibition of fluid takes place with such energy, that it pushes before it the fluid above; thus, if the stem of a vine, in which the sap is rising, be cut across, a bladder tied over it, will, after a short time, be burst by the fluid accumulated beneath it; or if a bent tube, containing a column of mercury, be affixed to it, the mercury will be raised to the height of forty inches or more. And that a force of attraction is exercised at the leaves, may be shown by placing the lower end of the upper division of the cut vine in water, when an active absorption and circulation of water will take place as long as the vital changes in the leaves go on; but if the vine be taken into a dark room, so as to check these vital changes, the absorption and circulation will likewise cease. So also the elaborated sap or latex, which, from its containing the elements for the nutrition and for the various secretions of the plant may be likened to the arterial blood of animals, circulates through a complex system of anastomosing vessels (like the capillaries of animals), in the under surface of the leaves and in the bark, and will ascend towards the stem, even against gravity, in a dependent branch. The circulation of these fluids takes place with the greatest activity in growing parts, in which nutrient and chemical changes are going on most actively.

Professor Draper, of New York,* has given a definite expression to the nature of the forces which operate in the production of the circulation of the sap in plants, and in that of the blood in animals. The laws of endosmose and exosmose resolve themselves into the following dogma: "That if two liquids communicate with one another in a capillary tube, or in a porous or parenchymatous structure, and have for that tube or structure different chemical affinities, movement will ensue; that liquid, which has the most energetic affinity, will move with the greatest velocity, and may even drive the other liquid entirely before it."

In plants, the rise of the ascending sap from the ground, results from the attractive force of the spongioles. These appropriate certain elements contained in the fluid, and exercise a more energetic attraction on a new supply, which pushes the former before it. Thus the sap ascends to the leaves, pushed on by successive new portions attracted to the spongioles. At the leaves, a new force of a similar kind, but due to the action of light, draws it on, and causes it to push before it the newly formed latex or elaborated sap, the flow of which is promoted by its affinity for the vegetable tissues which it permeates.

In the systemic circulation of animals, the arterial blood has a great affinity for the tissues to which it is brought by the capillary system. This force of attraction draws on the blood from the arte-

merely denoting that the force is exerted *at* the capillaries, whether it be exercised by their walls or by a mutual action between the blood within and the tissues outside them.

* On the Forces which produce the Organization of Plants. 1845.

ial side of that system, with a power which helps to propel on the deoxygenized blood into the venous radicles. In the pulmonary circulation, venous blood is conveyed to the air-cells by the pulmonary arteries. This kind of blood has a great affinity for the oxygen which is being continually brought to those cells by the movements of respiration. It is therefore forcibly attracted to the air-cells, and, being charged with oxygen, is pushed on by the succeeding portions of venous blood, which the same force is constantly attracting.

It is by the influence of an attractive force, such as Professor Draper describes, that we can best explain the continuance of a complex circulation in many of the lower animals in which no central organ of impulsion exists, as in some of the Polypifera, and of the Articulata. In the sponge, the remarkable currents of water which flow through the various channels that penetrate its substance, are maintained without any special propelling organ whatever. And the beautiful *cyclosis* in Chara and Valisneria affords a striking instance of a circulation without a *vis à tergo*.

In the vascular area of the egg, a circulation exists before a propelling organ. And in the acardiac fœtus a similar circulation exists, although in general it has such a connection with a second perfect fœtus that the heart of the latter may influence the circulation of the former. But that a fœtus may grow to a considerable size, and have its various tissues well developed without any connection with the twin fœtus, by means exclusively of a circulation of its own, of which a heart forms no portion, or upon which it can exercise but a very remote influence, is shown by the case put on record by the late Dr. Houston.* No doubt the same law which influences the movement of fluids in vegetable tissues would be in operation in such cases.

Now, with reference to the phenomena in the circulation of the blood in man above referred to, it may be asked: Is the assumption of the exercise of a capillary force necessary for explaining them? Can blushing, and other local determinations of blood, be accounted for, if we admit a *vis à tergo* as the sole force of the circulation? In order to explain the accumulation of blood, in the cheeks, for instance, under the influence of mental emotion, the advocates of the latter doctrine suppose the capillaries muscular, and affirm that a relaxed state of the walls of the capillary arteries, and perhaps also of the capillaries themselves, is produced by the nervous change which mental emotion excites. Such an explanation is perfectly admissible in this particular case, and it seems highly probable that in the relaxed state of the capillary vessels of the face, their walls yield under the pressure of the heart more than those of neighbouring vessels, which do not come so completely within the range of the centre of emotion. And in many persons, emotion causes the blood to desert the cheeks, which in consequence become pale. In such cases, the change in the nervous centre must excite an opposite, that is, a contracted state of the capillaries of the cheeks.

* Dublin Medical Journal, vol. viii.

But the accumulations of blood which are caused by local irritations, do not admit of satisfactory explanation by mere changes in the capillaries of the affected part.

For example, a particle of dust is thrown into the eye, and as long as it is in contact with the conjunctiva, its capillary vessels are turgid with blood. Is this due to a relaxed state of the capillaries caused by the presence of an irritating agent? The analogy of the influence of mechanical stimulation upon other vessels would lead us to infer that the irritation of a particle of dust in contact with the conjunctiva would cause the capillary vessels to *contract*, and a contracted state of these vessels would oppose rather than favour the accumulation of blood in them. It seems much more reasonable to suppose that the irritation caused by the foreign particle, increases the attractive force which the tissue naturally exercises on the blood; and this would give us a clue to explain the two kinds of congestion long recognised by practical men, the *passive* and the *active* form. The former is owing simply to a relaxed flaccid state of the parietes of the bloodvessels, which permits them to *receive* a greater quantity of blood from the heart, and to a *minus* state of the capillary force, the other to a *plus* condition of that force,—in virtue of which the tissue *attracts* a greater quantity of blood. To this latter form of congestion pathologists give the name of inflammation. Its phenomena, as observed under the microscope, are such as a *vis à tergo* alone could not develop. For not only are there dilatations of the vessels of the inflamed part, and a great afflux of blood towards a certain point or points in it, but the blood-corpuscles seem to rush thither, as if forcibly attracted towards each other, and also to some common focus. And the rapid and copious process of exudation, and the formation of pus-cells, which are so apt to follow an attack of inflammation, afford farther strong indication of augmented vital force in the inflamed part.*

So also in growing tissues, and in organs which enlarge at particular times, or under certain circumstances, the increased flow of blood to the part is a phenomenon in close analogy with the increased flow of sap to a bud; and is due, not to a *vis à tergo*, or to a relaxed state of bloodvessels, but to a demand from the tissue for more blood, an attractive force, by which the direction is regulated, and the quantity also. The annual renewal of the antlers of the stag, the enlargement of the testes of birds at particular seasons, that of the breasts of women during pregnancy and after parturition, all these cases afford instances in which a demand for blood is created at some point of the periphery, and a greater flow is established to the organs there placed than previously took place to them.

We can afford no satisfactory explanation of the localization of certain changes in the capillary circulation, unless on the hypothesis that the constituent elements of the affected parts are primarily diseased, and that their demand for blood is, in consequence, increased

* The theory of inflammation is extremely well discussed in Mr. J. Simon's Lectures on Pathology, Lect. IV. See also Mr. Paget's Lectures on Inflammation.

or diminished, and the flow of blood regulated accordingly. Thus the development of gout in a joint takes place often with such rapidity that it appears to the patient to be sudden; the train of phenomena being in such cases, first, a change in the tissues, so gradual as to be unperceived, then, an increased flow of blood, to such an extent as to cause the heat, the throbbing, and pain which characterize such affections. Again, certain poisons, which seem as it were to spend their force, in great part at least, on the skin, do not cause a change in the whole capillary circulation so much as in points of it, here and there, determining an increased flow of blood to this point and that, and leaving the intervening parts unaffected. The well-ascertained fact, *ubi stimulus, ibi fluxus*, cannot be so well explained on the hypothesis that the stimulus creates a relaxation of the tunics of the capillaries of the part, because that is opposed to analogy, as on the supposition that under the operation of the stimulus the demand for blood in the tissues is augmented, and the capillary force becomes exalted in the part, in virtue of which a greater flow of blood is determined to it.

The phenomena of asphyxia show that a stoppage of the circulation may take place at the capillaries, notwithstanding the continuance of the heart's action. When the access of air to the lungs is excluded, the circulation ceases at the pulmonary capillaries, and on examination after death the left auricle and ventricle are found quite empty, and the right cavities of the heart gorged with blood. The repletion of the latter cavities, and the emptiness of the former, indicate the position at which the obstruction to the circulation took place. Instantly the air is readmitted to the lungs, the blood assumes a bright red colour and the circulation goes on, indicating that the changes which take place between the air and the blood, must generate a force which exercises an important influence on the capillary circulation, and without which the heart's force is insufficient to propel the blood through the pulmonary vessels. Dr. John Reid* argues, as we think with justice, from the instantaneousness of the restoration of the circulation on the readmission of air, that its stoppage must be due to the cessation of the respiratory changes, and not to a contracted state of the capillary arteries as suggested by Mr. Erichsen, because the relaxation of those arteries, like their contraction, is a slow process, requiring two or three minutes to accomplish it.†

* John Reid, on the Cessation of the Vital Changes in Asphyxia. Phys. Researches, Edinb. 1848.

† Our friend and colleague, Dr. Geo. Johnson, has discovered a very interesting point, connected with the minute vessels of the kidney in cases of chronic nephritis with shrinking of the organ, which furnishes an additional instance of retardation or stoppage of the circulation at the capillaries, despite the continuance of the heart's action. Dr. Johnson shows that, under the influence of defective secretion, the renal circulation is greatly retarded in the *intertubular* capillaries, and that the *Malpighian* capillaries are consequently subjected to a greatly increased pressure and distension, giving rise to an escape of serum, or of blood, when a rupture of one or more of the minute vessels has occurred. When such a state of vessels has been of long duration, as in chronic inflammation of the kidneys, Dr. Johnson finds the capillary arteries much thickened, by reason of hypertrophy of their circular and longitudinal fibres, and a thick-

cavities of the heart are dilated, a much larger quantity of blood is regurgitated and a distinct venous pulse is visible in the superficial jugular veins, and sometimes in all the superficial veins which are distributed over the neck and upper part of the chest. The communicated venous pulse results simply from the proximity of some large artery, which in its pulsations communicates to the vein a movement of a similar nature.

Hales and Poiseuille estimated the force of the current of blood in the veins; the former by the introduction of tubes into the large veins, as in his experiments upon arteries; the latter by the hæmadynamometer; and their observations have lately been repeated by Valentin and Mogk. Hales found that the blood rose to four feet two inches above the level of the heart, in a tube inserted towards the head into the jugular vein of a mare, the blood rising several inches when the animal strained, but subsiding again when he became quiet; hence it is plain that the force of the heart, competent as it is to maintain a column of such a height, must be amply sufficient to return the blood to the heart. Valentin and Mogk's observations show that the force of the blood in the veins of dogs is equal to one-eleventh or one-twelfth of that in the corresponding arteries.

The venous circulation is influenced a good deal by the respiratory movements, which tend partly to promote, partly to retard it. These effects are produced most plainly by the forced movements of respiration. Thus a deep inspiration, by enlarging the capacity of the chest, generates a tendency to a vacuum, which, under the pressure of the surrounding atmosphere, is filled chiefly by the rush of air into the trachea, and through it to the lungs, but partly by the afflux of the blood, which must be principally venous, since the semilunar valves would oppose any reflux in both the great arteries. Sir David Barry illustrated the influence of inspiration in favouring the centripetal flow of blood. He introduced one end of a bent glass tube into the jugular vein of a horse, the vein being tied above the point at which the tube was inserted; the other end of the tube was immersed in a coloured fluid. At each inspiration the fluid rose in the tube, being drawn towards the chest, whilst during expiration it sank or remained stationary.

Forced expiratory efforts, on the other hand, retard the venous circulation, as may be well illustrated by holding the breath for a few seconds, or straining strongly, when the veins, especially those of the neck and chest, will swell up and become distended; but as soon as the breathing is restored, they return immediately to their former size. Hence it is that persons subject to frequent disturbances of the respiratory actions, as in asthma or dyspnœa of any kind, exhibit, after a time, more or less enlargement of the venous system.

Disturbances in the respiratory actions seem to affect the circulation and especially that in the veins, more extensively in another way, namely, through the pulmonary capillaries. The imperfect respiratory changes, consequent upon the disturbed breathing, retard the flow of blood through the capillary plexus, which undergoes, by

the dilatation and rupture of the air-cells, considerable stretching and widening of its meshes, and even becomes obliterated in parts. These changes also create additional obstacles to the pulmonary circulation, which impede the flow from the right ventricle, and increase the backward pressure of the blood on the walls of that cavity, causing it to become dilated and hypertrophied. It is in this way that are produced the hypertrophy and dilatation of the right cavities of the heart, which, to a greater or less extent, are invariable consequents of frequent attacks of asthma or bronchitis.

The influence of the respiratory movements upon the venous circulation is shown in the clearest manner by the use of the hæmadynamometer, as in the experiments of Poiseuille, Magendie, Ludwig, Valentin, and Mogk, the column of mercury rising in expiration, and falling in inspiration; and these experiments likewise prove that this influence is only felt in the large veins near the chest, and not in the more distant ones. The influence of expiration in retarding is much more powerful than that of inspiration in promoting the venous circulation; for the same physical condition of the chest which exists at the commencement of inspiration, and which favours the rush of blood to it, tends rather to delay the escape of blood through the arteries, and the heart's action is thereby much weakened and often depressed.

Muscular movements likewise favour the venous circulation, as is well shown in the operation of venesection, when the patient is made to move his fingers freely, the flow of blood from the vein being thereby immediately increased. It is the action of the valves which determines the centripetal flow of the blood in the veins under muscular pressure; for, as the contracting muscles simply compress the veins, the blood would be driven either or both ways; but the valves affording a direct impediment to the centrifugal flow, it is forced to take the opposite course. This is obviously one of the ways in which exercise favours the circulation and promotes the general health.

It has been supposed that the contraction of the auricles by partially emptying those cavities, calls into play an elastic force in their walls, which favours the rush of blood into them, and that thus a certain suction power of the auricle may be enumerated among the forces which aid the venous circulation. The idea is illustrated by exhausting an India-rubber bag, to which a glass tube is attached, and then immersing the open extremity of the latter in a vessel of water, when the water will pass freely into it under the influence of the atmospheric pressure on the water. The principal fact in favour of this view is the experiment of Wedemeyer, which is thus detailed by Müller: "Wedemeyer and Guenther having tied the jugular vein of a horse, made an opening into it between the ligature and the heart, and introduced a catheter, to which a bent glass tube had been cemented. The longer descending branch of the tube (two feet in length) was placed in a glass filled with water. At first, the inspirations and the contractions of the heart were nearly simultaneous, and of the same frequency—namely, thirty in a minute—and the coloured water rose suddenly two or more inches in the tube

at the moment of each inspiration and pulsation of the heart, and sank again each time to its former level. The inspirations gradually became twice as frequent as the pulsations of the heart, and Wedemeyer and Guenther now observed, for a long period, that the rise of fluid did not take place at each inspiration, but at every beat of the heart, and, consequently, simultaneously with each dilatation of the auricle. This experiment," adds Müller, "seems to prove beyond doubt that the heart exerts a power of suction." It is most probable, however, that this power is extremely small, and that it does no more than counteract the obstructive influence which would otherwise arise from the regurgitation which takes place into the large venous trunks from the auricles at each systole.

The veins possess a certain tonic influence similar to that of arteries, by which they can adapt themselves to the varying quantity of their contained blood. This is, doubtless, due to the presence of muscular fibres in the tunics of veins already described; the power of these fibres to alter the caliber of the vein is clearly demonstrable by the influence of galvanism,* which causes an appreciable diminution in the size of the vessel at the point of transit of the current.†

The flow of blood in the veins, then, it may be concluded, is maintained chiefly by that same force through which it is driven through the arteries and capillaries, aided by the sort of suction in the centripetal direction which is caused by inspiration and by the diastole of the auricles, and promoted likewise by the contraction of the various muscles, among or through which the veins pass, and by the position and mechanism of the valves.

It is proper to observe that the venous circulation being moved by less force than the arterial (the heart's power having already very much expended itself on the arteries and capillaries), is more influenced by gravity—either favourably or otherwise—than the arterial. Hence, in dependent positions, as in the lower extremities, when the blood has to ascend against gravity, the veins are apt to swell, and to acquire a permanent dilatation and thickening of their coats from the retardation of the current in them. It is important

* See Kölliker's experiments—Siebold and Kölliker's Journal.

† While these pages were passing through the press (Feb. 1852), Mr. Wharton Jones announced, in a paper read to the Royal Society, the discovery that the veins of the bat's wings contract and dilate *rhythmically*, and that they are provided with valves, some of which completely, others only partially, oppose regurgitation of blood. The rhythmical contractions and dilatations are constantly going on, and that at the rate of ten contractions in the minute. During contraction, the flow of blood in the vein is accelerated, and on the cessation of the contraction the flow is checked, with a tendency to regurgitation. But this check is usually only momentary; already, even while the vein is in the act of again becoming dilated, the onward flow recommences and goes on, though with comparative slowness, until the vein contracts again. It is the heart's action which maintains the onward flow of blood during the dilatation of the vein, whilst it is the contraction of the vein coming in aid of the heart's action, which causes the acceleration. Mr. Jones states that he has not been able to observe unequivocal evidence of tonic contractility in veins, as Kölliker's experiments indicate; he likewise affirms, in opposition to a statement of Mr. Paget, quoted at p. 662, that nowhere do the arteries and veins of the bat's wing communicate, the only communication being the usual one through the medium of capillaries.—*Proceedings of the Royal Society*, Feb. 1852.

that this fact should be kept in view by the practitioner in the treatment of varicose veins, and of anasarcous states of the limbs.

We have seen that the blood moves in the arteries with considerable velocity, and likewise with great, although much diminished, rapidity in the capillaries; its rate of motion increasing again in the veins, especially in those nearest the heart. It may be inferred from these facts, that any given particle may complete the round of the circulation in an exceedingly brief period. It is an important problem—especially with reference to the time in which poisonous substances introduced into the blood may produce their effect—to determine in what space of time a substance introduced into one part of the circulation may reach the most distant part; or how soon, for instance, a substance inserted into the *right* jugular vein may, after traversing the right heart, the pulmonary circulation, the left heart, the systemic arteries, return to the systemic veins, and be found in the *left* jugular vein.

In the present state of our knowledge no exact solution of this problem can be given. But a very close approximation to the truth may be obtained—first by calculation, secondly by experiment. By calculation, we can determine in what space of time the whole blood of the body may circulate through the heart. The data for this problem are, the weight of the whole quantity of blood in the body, the quantity of blood expelled at each systole from the left ventricle, and the number of systolic actions in a minute, or, more exactly, the duration of a pulse. It is plain that, if the left ventricle contract seventy times in a minute, and at each contraction expel five ounces of blood, according to Valentin, or six ounces ($\frac{1}{400}$th part of the weight of the body), according to Volkmann, a quantity of blood equal to that of the whole body will in that space of time pass through the heart. It may, then, be assumed from calculation, that the circulation may be completed in a period of time, which, in round numbers, may be expressed as one minute.*

Hering was the first to experiment on this subject, his object being to ascertain how soon a substance easily recognized (as ferrocyanide of potassium), when introduced into one part of the circulation as the right jugular vein, could be detected in a distant part of the circulation as the left jugular. Hering found that this substance would

* Volkmann's formula is $t = z\frac{x}{y}$ where t is the required mean time of the completion of the circulation, x is the whole quantity of the blood, y the quantity expelled at each systole, and z the mean duration of a pulse. Whence, taking the mean quantity of x at 30 lbs., and of y at 6.2 ounces, the duration of a pulse being 0.85 of a second, we get $t = 0.85\,\frac{15000}{188} = 67.5$ seconds. And as, according to Valentin, the whole quantity of blood is equal to about 1-5th the weight of the body, and as from Volkmann's researches the quantity expelled at each systole of the ventricle is $\frac{1}{400}$th of the weight of the body, calling this weight p, then $x = \frac{1}{5}p$ and $y = \frac{1}{400}p$, and $t = z\,\frac{80\,p}{p}$, therefore $t = 80\,z$; whence it appears that the time of the circulation is directly as the duration of a pulse, and inversely as its frequency.

pass from the right to the left jugular veins in from twenty to thirty seconds; and from the jugular vein to the great saphena in twenty seconds; from the jugular vein to the masseteric artery in from fifteen to thirty seconds. Results quite confirmatory have been obtained from like experiments by Poiseuille, and also by Blake. The former found that ferrocyanide of potassium, with acetate of ammonia, or nitrate of potash, passed from one jugular vein to the other in from eighteen to twenty-four seconds; but that the addition of alcohol retarded the rate of transit to from forty to forty-five seconds. Blake found that nitrate of baryta passed from the jugular vein of a horse to the opposite carotid artery in from fifteen to twenty seconds. He found also that the poisonous influence of strychnia on the nervous system, showed itself in twelve seconds after injection into the jugular vein; in a fowl, in six seconds and a half; and in a rabbit in four seconds and a half.*

The results obtained from calculation, as regards the rate of the circulation, are less conclusive than those by experiments; for the obvious reason that we have only the approximative value of the two principal quantities which enter into the calculation, namely, that of the mass of blood in the body, and that expelled at each systole. But the results of the two modes of inquiry are sufficiently near to each other to denote that the round of the circulation is completed by any given portion of blood in a marvellously brief period, which, in man, probably, rather falls below than exceeds a minute. We need not, therefore, have recourse to any other hypothesis to explain the rapid effects of certain poisons, than that they enter the blood, and with it are whirled with immense velocity through the substance of the most vital organs.

* Hering in Tiedemann and Treviranus Zeitschrift fur Physiol. b. iii. Poiseuille's Ann. des Sc. Nat. 1843. Blake, Edin. Med. and Surg. Journal, 1841. See also on this subject Volkmann's 10th chapter.

On the subjects discussed in the preceding chapter, the reader is referred to the various systematic works on Physiology, to the supplement lately published by Valentin, and to Dr. Allen Thompson's very comprehensive article, Circulation, in the Cyclopædia of Anatomy and Physiology. On the anatomy and physiology of the heart, Kürschner's article in Wagner's Handworterbuch, and Dr. Jno. Reid's article in the Cyclop. of Anat. may be consulted; and as regards its motions and sounds, we refer to the reports of the Committee of the British Association, collected in the Appendix of Dr. C. J. Williams's work on Diseases of the Lungs, to Dr. Blakiston's admirable work on Diseases of the Chest, to Dr. Walshe on Diseases of the Heart and Lungs, and Dr. Herbert Davies on the same subject; and on the physics of the circulation, to Hales's Statical Essays, vol. ii.; to Dr. Young's Croonian Lecture on the Functions of the Heart and Arteries, Phil. Trans. 1809, and Medical Literature, p. 605; Poiseuille sur la Force du Cœur Aortique, in Magendie's Journal, vol. viii., and his essay, Recherches sur l'Ecoulement des liquides considéré dans les Capillaires Vivans, in the Journ. des Sc. Nat. 1843; to the Essays of Ludwig, Spengler, and Mogk, in Müller's Archiv; Magendie, Leçons sur les Phénomènes Physiques de la vie, and especially to the very able work of Volkmann, Die Hæmodynamik nach Versuchen, Leipzig, 1850, which we only received when these pages were in type. The following works may also be mentioned as containing interesting matter relating to the circulation in general: Dr. Graves's Clinical Lectures, lect. i. on the Circulation; Dr. Todd's three Clinical Lectures on the Pulse, Lond. Med. Gaz. 1851; Draper, on the Forces which produce the Organization of Plants, New York, 1845; Prof. Jno. Reid's essay on Asphyxia, in his Physiological and Pathological Researches, ed. 1848.

CHAPTER XXIX.

ON RESPIRATION.—COMPARATIVE ANATOMY OF THE RESPIRATORY ORGANS.—ANATOMY OF THE HUMAN LUNGS.—TRACHEA.—BRONCHI.—BRONCHIA.—ULTIMATE PULMONARY TISSUE.—MOVEMENTS OF RESPIRATION.—FREQUENCY OF RESPIRATIONS, AND RATIO TO THE PULSE.—AERIAL CAPACITY OF THE LUNGS, AND AMOUNT OF AIR BREATHED.—CHANGES IN THE RESPIRED AIR, CARBONIC ACID EXHALED—OXYGEN INHALED.—CHANGES IN THE BLOOD.—NATURE OF THE RESPIRATORY PROCESS.

RESPIRATION is that function by which an interchange of gases takes place between the interior of an organized being and the external medium; and in the animal kingdom oxygen is the gas received, and carbonic acid the gas given out. Every part of the surface to which the outer medium (whether air or water) has access may be considered to share in respiration; but in all, except some of the lowest animals, special organs are provided in which the interchange can be more readily effected. These organs in all cases consist of a membranous surface, adapted for contact with the surrounding medium, and capable of exposing the fluids of the body in an especial manner to the action of the air. The interchange of the gases through this *respiratory membrane* is essentially a purely *physico-chemical* phenomenon, and must be studied as such. The very great variety of structures with which different animals are furnished for this function, merely present us with modifications of the elementary conditions whereby its activity and extent are governed in the several instances. The contact of air with the blood may be influenced (1) by atmospheric concentration or dilution. In water-breathing animals, the air breathed is that held in solution in the water, and is of course in very small quantity. The density or rarity of the air, according to temperature and barometric pressure, may perhaps affect the activity of respiration in air-breathers. (2) The extent of the respiratory surface; (3) the thickness of the tissue between the air and the blood, and (4) the more or less complete manner in which the general mass of the blood is brought from the tissues to the respiratory surface—all these exert much influence on the activity of respiration.

Comparative Anatomy.—In *Entozoa*, *polyps*, and *medusæ*, no special respiratory organ exists. In star-fishes and sea-urchins, among the *echinodermata*, the sea-water gains access to cavities among the viscera, and is renewed continually by special organs, principally cilia. The holothuria has an internal system of arborescent tubes opening from the cloaca, receiving water, and, according to Tiedemann, serving for respiration; its branches end in vesicles. In *annelida*, there are sometimes tufted *branchiæ*, or gills, as in the arenicola, or sand-worm; sometimes sacs opening separately, as in lumbrici and leeches. The *crustacea* have branchiæ attached either to the feet or abdominal surface. Of the *arachnida*, some, as the scorpion, have pulmo-

nary sacs, or *lungs*, with parallel lamellæ, situated on the abdomen in from one to four pairs, and each opening by a separate stigma; others have a system of ramified internal air-tubes, termed *tracheæ*, or *spiral vessels* (from a spiral thread in their wall); and some both tracheæ and pulmonary sacs. The *myriapoda* and all the *insecta* have tracheæ. These penetrate the internal organs to their remotest parts, anastomosing freely, and open at several points on the surface. Insects which breathe in water, as well as many aquatic larvæ, have branchiæ which first separate air from the water, and then transmit it along the tracheæ. The respiration by tracheæ is probably a very perfect one, the blood and tissues being aerated throughout the body, at every spot in which they are being deteriorated.

Among *Mollusca*, some have *branchiæ*, or gills, as the cephalopods, the conchifera, and some gasteropods. Other gasteropods have a pulmonary sac, or *lung*, *e. g.* the common snail. This sac opens and shuts so as to change the air, and on its surface the venous blood is distributed ere it reaches the heart.

Fishes present the greatest development of *gills*. There are four branchial arches, bearing vascular plates with lateral offsets. Matteucci estimates the surface of the gills of the common ray to measure 2,250 square inches. All the blood is driven by the heart, through the gills, to the aorta, and thus comes into close proximity to the water in contact with the branchial surface. The capillary network has close and regular meshes.

Reptiles have a rudimentary form of lung, combined in many instances with gills, during a part or the whole of life, *e. g.* in the frog, the gills exist only in the tadpole state; in the proteus, they remain through life. The pulmonary sacs of reptiles are more or less cellulated on their inner surface, and receive a portion only of the venous blood in each circuit.

In *Birds* and *Mammalia* respiration is much more active, being performed by means of large and highly-divided lungs, placed within a bony framework, capable of receiving and rapidly renewing the air in large quantities, and giving passage to the whole blood of the body on its way from the veins to the arteries. In Birds, there is a series of openings from the pulmonary air-tubes, by which the air gains access to passages and spaces among the other organs and tissues, rendering the body specifically lighter, and, perhaps, in some degree, aiding respiration. Farther varieties in the structure of the lungs, modifying their respiratory power, will be alluded to when the human lungs have been described.

Organs of Respiration in Man.—The *lungs*, placed in the thoracic cavity, receive *air* by the nasal passages and trachea, and *venous blood* from the right side of the heart to transmit it to the left. They form a double organ, with a single common air-tube, the *trachea*, and a single common *pulmonary artery*, supplying the venous blood. These vessels branch first into a right and left, and then into many subordinate ramifications up to the ultimate air-cells and capillaries. Four veins carry off the aerated blood to the left side of the heart. Being penetrated by the air, the lungs are the lightest organs in the body. In the fœtus, before breathing, they are small, and transmit only so much blood as is requisite for their own growth; but when the air enters their volume augments, their absolute weight increases in consequence of the greater afflux of blood, while their specific gravity diminishes. Krause estimates the average absolute weight of the lungs in men to be three pounds and a half, in women two pounds and three-quarters, and the left to be smaller than the right by one-tenth. The weight, as compared with that of the whole body, is as one to forty or fifty.

In shape, the lungs are adapted to that of the cavity in which they are lodged; their apices rise into the neck, their bases rest on the diaphragm, between them lies the heart with the great vessels. They are invested by a serous covering, the pleura, which, after lining the thoracic walls, is reflected over them at their root, and dips into

those fissures, which serve to subdivide them imperfectly, the right into two, the left into three, *lobes*.

The *trachea* descends in the middle line from the *larynx* (which is a complicated development of it for the protection of the orifice of the respiratory organ, and for the production of sound, and which will be afterwards described), as far as opposite the second or third dorsal vertebra, being straight, sub-cylindrical, flat behind, and about three-quarters of an inch wide. It is held permanently open by from sixteen to twenty cartilaginous rings, flattened in the direction of the wall in which they are imbedded, and deficient behind to an extent of one-third. Of these, the highest is the thickest, and the lowest is adapted by its shape to the bifurcation of the trachea into the two bronchi. The free ends of these cartilages are sometimes forked, and contiguous ones are now and then joined. They are immediately invested with perichondrium, a dense, white, fibrous, inelastic membrane, and are connected by a continuation of it extending between their borders and ends. This inelastic membrane, by its toughness, resists undue extension in the longitudinal direction.

Looking on the trachea behind, we observe the space between the ends of the cartilages covered with irregularly interwoven fibres, in the course of which we have discovered unstriped muscular fibres to occur, especially about the bifurcation. In this fibrous layer are recesses for the tracheal glands, and on dissecting it off these glands are exposed, together with a thin sheet of transverse unstriped fibres, completing, as it were, the circle of the cartilaginous rings, and known as the *trachealis muscle*. The fibres of this are attached a little way from the extremities of the cartilages on their inner surface, and in contraction must serve to approximate them, and thus to narrow the canal. In the horse, they are inserted three-fourths of an inch from the extremities, which almost or quite overlap. In birds, they are composed of striped fibres.

The cartilages, their interspaces, and the trachealis muscle are lined by a thin layer of longitudinal, elastic, anastomosing fibres, uniformly spread out except over the trachealis muscle, where they are gathered up into longitudinal bands, sometimes one-twelfth of an inch thick, very visible through the mucous membrane. These take a serpentine course down the bronchi, and preserve their anastomosing character. The trachea owes its elasticity in the longitudinal direction to the fibres now described.

The mucous lining of the trachea, the essential part of the duct, to which the above are accessory, is continuous through the glottis with that of the pharynx, and physiologically with the respiratory compartment of that cavity, and with the nasal passages (see ante p. 522). It is covered with ciliated epithelium, and the direction of the movement is probably upwards towards the glottis. The *tracheal glands* are productions of this membrane, and appear as a layer of reddish, distinct granules, behind the trachealis muscle, each one being furnished with a separate duct, traversing first the muscle and then the layer of longitudinal elastic fibres, to open on the inner surface of the tube. These glands appear to be tubular, not follicu-

air, and are thus related rather to the sudoriferous than to the salivary system. They probably furnish much of the halitus of the breath and may determine its odour.

Of the *bronchi* or primary subdivisions of the trachea, the right is the shorter, wider, and more horizontal; the left longer to pass under the aortic arch. Their walls resemble those of the trachea with slight modifications. At the root of the lung, each breaks up into branches corresponding to the lobes (*lobal bronchia*), and these again into *secondary*, *tertiary*, and *terminal* bronchia, the last named being from one-fortieth to one-sixtieth of an inch in diameter. The terminal bronchia pass to portions of the pulmonary substance more or less distinctly mapped out by areolar tissue, and termed *lobules*.

Coats of the Bronchia.—All these become gradually thinner as they approach the air-cells. The cartilaginous pieces, which are irregular in shape and position in the lobal bronchia, become reduced to mere flakes, and finally cease in those of one-sixth or one-tenth of an inch in diameter (Fig. 204). The last are seen mostly where branchings occur. The muscular fibres of the trachea are continued down even to the terminal bronchia, but instead of filling up only the gap in the cartilaginous framework, they form a uniform layer encircling the canal, but excessively thin. The fibres are here arranged in anastomosing bundles (Fig. 203). Within the muscular layer is that of the longitudinal elastic fibres, here disposed as an even layer, and representing the submucous areolar tissue. The ciliated epithelium and the basement-membrane of the mucous tissue both descend into the terminal bronchia. On the exterior of the bronchia is some areolar tissue separating them from the neighbouring masses of air-cells, and associated with the arteries, veins, lymphatics, and nerves belonging to the bronchial wall.

Fig. 203.

Small bronchial tube laid open, showing the transverse plexiform arrangement of the muscular layer, and its disposition at the orifice of a branch. From a man æt. fifty.—Magnified 2 diam.

The *bronchial arteries* are usually two, coming from the aorta, but irregular. They supply the coats of the bronchia, and have corresponding veins. Their capillaries anastomose with those of the pulmonary artery where the terminal bronchia become lobular passages. The distribution and actions of the pulmonary nerves have been already discussed (pp. 498–506).

Ultimate Pulmonary Tissue—Lobules.—In some parts of the exterior of the lungs, particularly near the borders, and in some animals throughout, may be noticed a sort of mapping out of the pulmonary substance into small polyhedral masses separated by areolar tissue, and having a very irregular shape. These are the *lobules* of the lungs. They can only be made out in certain situations, even by dissection, for it does not appear that the whole human lung is thus subdivided by areolar septa. Nevertheless, it seems certain that each terminal twig of the bronchus is in relation with only its own proper set of air-cells, and that such sets of cells do not communicate except through the medium of the bronchia. In

this sense lobules exist everywhere, even when not isolated by areolar tissue, and in this sense we shall use the term, as conveniently designating that series of air-cells, associated by dependence on a single terminal air-tube. We shall afterwards show how much difference exists in the isolation of the lobules of the *liver* even in allied animals, and how unimportant this variety appears to be.

Fig. 204.

Small bronchial tube laid open, showing the arrangement of the last cartilaginous flakes. The tube has been cut across above, at the point where it penetrates the substance of the lung, and below where it has a diameter of about 1-12th of an inch. The elastic and muscular fibres are not represented, but both were so delicate as to allow the adjacent air-cells to be seen through the bronchial wall. Ciliary epithelium was traced in the finest tube that could be opened by scissors, viz. of 1-40th inch diameter. From a healthy man æt. twenty-five. Natural size.

The superficial lobules derive a covering on one aspect from the pleura, but are separated from it by rather dense areolar tissue, which may be dissected off without rupturing the air-cells. If the interstices between contiguous superficial lobules be explored by the knife, the terminal bronchia are found at the bottom of the fissures, each going to a single lobule, and besides these are seen branches of the pulmonary artery and vein, not running in company, nor limiting themselves to a single lobule, but common to contiguous lobules; so that the air-spaces of one lobule do not communicate with those of another across the interstices, but the bloodvessels do. On the exterior of a lobule we observe bubbles of air of various sizes in its tissue, and if the bronchial tubes be injected, the lobule is distended, and its exterior presents a number of bulgings known as the *air-cells*, about which much controversy has existed. Their shape seems irregularly polyhedral, like the lobules themselves. The angles where three or more of these cells meet, are the points at which the terminal twigs of the pulmonary artery and vein penetrate among the cells, after meandering more or less over the surface of the lobule. In their course in the interior of the lobule, these twigs generally run separately in the lines of junction of three or more cell-walls, branching as they run, and breaking up into their capillaries on either hand.

As the superficial lobules are truncated where they form the surface of the lung, so the cells are truncated where they form the surface of the lobule. This is most decidedly the case where the lobules are well defined, and admit of separation; but where contiguous lobules are not isolated by areolar tissue (as in most parts of the interior of the lungs, and in the lungs of the smaller mammalia), their superficial cells have their inequalities mutually adapted to each other, and even their walls fused together, so that the lobules would not remain distinct, were it not that their air-cells do not communicate across the interval.

To convey a correct, and at the same time a simple, idea of the constitution of the pulmonary lobules, we must regard each as an

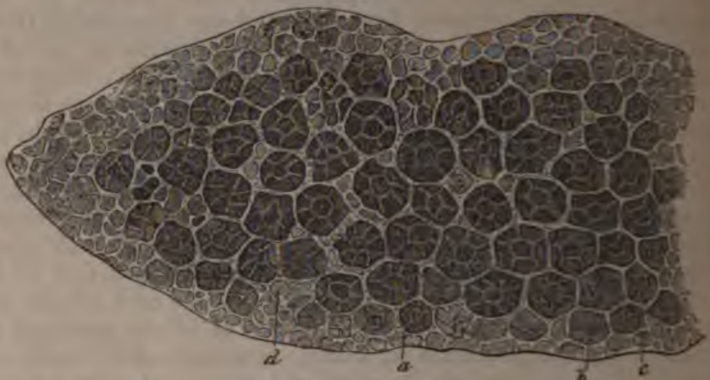
ntary lung, perfect in itself as an arrangement of a respiratory rane adapted to the aeration of the blood. First, the terminal nial tube pertaining to each lobule, loses its epithelium and lar tunic at about one-eighth of an inch distant from the last l to which it leads, and is thus reduced to basement tissue and r elastic fibres, which become blended into a single coat, the nembrane composing the tubes beyond, and the air-cells. The ıal bronchial tube, thus simplified, ramifies within the lobule, s branches may be conveniently distinguished from the bronchial under the name of *lobular passages.** The lobular passages ider than the terminal bronchia, and are remarkable (being combed on their interior) for presenting a series of sacculi or n their wall. These are the pulmonary *air-cells*. They form ıber of bulgings of the wall, and are separated from one another ta projecting inwards from the wall toward the axis of the pas- Fig. 206). They each open separately into the lobular passages, o not communicate with each other except through the passages. erminations of the several lobular passages are air-cells coming the surface of the lobule, but some of the air-cells placed lly on the passages also contribute to form the surface of the . The air-cells thus surround and terminate each lobular pas- -and the lobule consists of a number of lobular passages, as- ed by their dependence on a single terminal bronchial tube, and clothed as it were, on its sides and at its end, with a honey- of air-cells, with orifices open towards the cavity of the passages. guous cells of the same passage are separated by a simple septum ocess of the wall, while the contiguous cells of neighbouring ges are separated by a septum, likewise simple, formed by the of the walls of each. Where the septa spring from the wall passage, or in the angles where neighbouring cells unite, the s strengthened by a greater thickness of elastic tissue, which has the form of arching bands of considerable strength in these ions, as well as around the orifices of the cells. Thus the ır passages and the air-cells are formed of one tissue, and rm the same function. They are a series of branched cellulated ssages, not lined with epithelium, or coated with muscular , but highly extensible and elastic, of much larger aggregate ity than the terminal bronchia which lead to them, and resem- closely, in general conformation, the reptilian lung. Indeed, mirable notion of the essential arrangement of the lobules of the nalian lung may be derived from an examination of the terminal of the sacculated bronchia of the lung of the turtle. The ır passages are wider than the terminal bronchia of which they he continuations, and than the cells which pullulate on their They also branch again and again in order to spread from rminal bronchial tube on every hand throughout the whole area e lobule; and as their ramifications observe no certain order or), it happens that sections carried through the lobules are

* Dr. W. Addison, Phil. Trans. 1840.

rarely found to follow any single passage far, so as to display, in a happy manner its mode of distribution. Sometimes, however, this is better seen than at others.

[M. Rossignol has recently given an elaborate description of the pulmonary structure. He insists particularly on the ultimate bronchial ramifications being in shape like an inverted funnel, and he terms them the *infundibula*. The cells, forming a honeycomb on their interior, he calls the *alveoli* (Figs. 205 and 206). Emphysema,

Fig. 205.

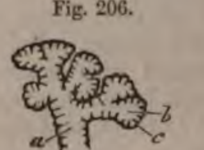


Thin slice from the pleural surface of a cat's lung, considerably magnified. At the thin edge, *alveoli* are seen. In the centre (as *a*), where the slice is thicker, alveoli are seen on the walls of *infundibula*.—From Rossignol.

according to this author, seems to consist in a distension of the passages and cells, and a breaking down and obliteration of the septa, first between the cells of the same passage and then between neighboring passages, and even between contiguous lobules.

The diameter of the lobular passages is from $\frac{1}{100}$ to $\frac{1}{200}$ of an inch; and that of the cells from $\frac{1}{200}$ to [illegible] of an inch according to our measurements. In a preparation of the lung of the calf, given us by our friend Professor Retzius, they measure $\frac{1}{800}$; and Dr. W. Addison makes them from $\frac{1}{200}$ to $\frac{1}{300}$ of an inch.—Ed.]

Fig. 206.



Bronchial termination in the lung of the dog. *a*. Tube (lobular passage) branching towards the infundibula. *b*. One of the infundibula. *c*. Septa projecting inwards on the infundibular wall and forming the alveoli, or cells. —From Rossignol.

The skeleton of the lobule is thus an elastic membrane elaborately arranged, so that the air may be brought into contact with it for the most part on both its surfaces. Over this membrane the whole venous blood of the body is made to course in a continual stream, so as to be submitted to the action of the air.

Vascular Element.—The *pulmonary artery*, conveying the venous blood to the lungs, is about as large as the aorta, and is furnished with a triple valve at its origin from the right ventricle of the heart. It soon divides into a right and left branch, which enter the lungs at their root, and ramify as far as the lobules, in company with the

ronchia. Arrived at the lobules, the small branches of the pulmonary rtery do not enter in company with the lobular passages, but disribute themselves over the lobules in the interlobular fissures, penerating at various points between the air-cells, and occupying tubular hannels in the angles where three or more cells meet. These chanels are formed of the same yellow elastic tissue which constitutes he lobular passages and air-cells, and their wall blends with the roper coat of the terminal twigs of the pulmonary artery which ccupy them. The capillaries of the lobule are given off both from he twigs which meander over the lobule and from those which penerate it, and they form a network which covers the walls of all the ells of the lobule, as well as of the lobular passages, anastomosing ith some twigs of the bronchial arteries where the passages are ontinuous with the terminal bronchia. This network empties its lood into venules which lie first in intercellular channels similar but ntermediate to those which lodge the arterial terminations; and hese venules collecting the now aerated blood from the interior and lso from the surface of the lobules, converge to larger veins which e in the interlobular spaces and tend towards the root of the lungs, ut for the most part by a route distinct from that of the arteries nd bronchia. Thus the general mass of the lung may be regarded s containing two series of ramified canals, one transmitting the ronchia (with their vessels and nerves) and the pulmonary arteries, he other the pulmonary veins. This interesting fact was well escribed by Dr. Addison, of Guy's Hospital, in a paper in the *Medico-Chirurgical Transactions* in 1840. At the root of the lungs our pulmonary veins result, which forthwith discharge their torrent f arterialized blood into the left auricle of the heart.

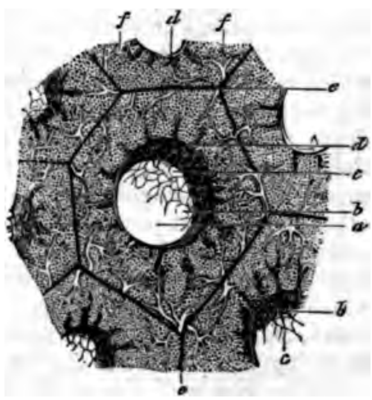
The cause of the separate course of the pulmonary arteries and eins is to be found in the opposite position of their radicles, in reard to the capillary network of the lobules, it being a convenient rrangement for the terminal arterial and venous twigs to hold alterate positions among the capillary network, so that each arterial wig disperses its blood in all directions, and each venous radicle ollects it from all sides. An obvious analogy exists in respect of he course of the vessels and ducts between the liver and lungs, the ile-ducts answering to the air-passages, the hepatic artery to the ronchial arteries, the vena porta to the pulmonary artery, the epatic vein to the pulmonary vein. The nerves and lymphatics ass in both cases with the ducts.

The capillary network of the lungs lies on and in the walls of the ir-cells and lobular passages. These walls are for the most part uch too thin to inclose the capillaries between two layers of their ubstance, and therefore the capillaries project fairly into the airells, by a great part of their circumference, being adherent to the all by a narrow line only. The capillary wall is thus exposed and are, in contact with the air of the cell, and nothing besides the elicate membrane of the capillary intervenes between the air and he blood. A capillary frequently passes through an aperture in the

arrangement of the capillaries and terminal air-passages, lately made by Mr. Rainey. This careful and accurate anatomist was the first to insist on the fact that, in mammalia and birds at least, the capillaries are, as we have above noticed, *bare;* exposed on their exterior to the air, not covered by any membrane, either mucous or serous, or by any epithelium; and that by this arrangement the most perfect aeration of the blood which traverses them is provided for. The air and the blood may be said to be in contact through the delicate capillary wall, a film less than $\frac{1}{20000}$ of an inch in thickness. In some of the mammalia, as the kangaroo, the rat, and the mouse, the terminal air-spaces are too minute to contain even a single particle of epithelium, and cannot therefore be lined by a pavement of such particles. The elastic tissue described as forming the cell-wall in the human lung is in such instances very imperfect, being deficient in the areolæ of the vascular network, so as to render the cell-walls cribriform, or rather to reduce the terminal air-receptacles into a congeries of inosculating and most minute and irregular passages.

In the bird's lung, the elastic tissue, according to the same anatomist, is even more scanty. The mucous membrane lining the bronchia ceases at the commencement of the lobular passages, and these passages seem hollowed out in the substance of a solid capillary plexus, or one in which the capillaries extend and anastomose indifferently in all directions. This vascular plexus forms the only wall of these passages, and the air has access from the passages into the interstices of the plexus, so as everywhere to surround and touch the whole surface of every capillary. Instead, therefore, of the terminal air-spaces being cells with a plane network of capillaries on their walls, they are the mere interstices of a solid vascular plexus. Thus, a more abundant intermixture of the blood and air is secured, and the ultimate tissue of the lung is reduced to the simple capillary wall, arranged so that air has access to its exterior. The adhesion of the lungs to the costal surface, and the support afforded by the cartilaginous and other tissues of the bronchial tubes, as well as by the areolar tissue bounding the elongated lobules, are sufficient to maintain the integrity of so frail a web. The aerial interstices of the vascular plexus are usually even smaller in diameter than the capillaries themselves, and, according to Mr. Rainey, average $\frac{1}{3000}$

Fig. 208.



Slightly oblique section through a bronchial tube, showing at *a* the cavity of the tube. *b.* Its lining membrane, containing bloodvessels with large areolæ. *c, c.* Perforations in this membrane, where it ceases at the orifices of the lobular passages, *d, d.* *e, e.* Spaces between contiguous lobules, containing the terminal pulmonary arteries and veins supplying the capillary plexus, *f, f.* to the meshes of which the air gains access by the lobular passages.

of an inch. The above Fig. (208) is from Mr. Rainey's paper, and is drawn from the lung of the fowl, highly magnified.

The gradations of perfection in the respiratory surface, considered as to its minute organization in Reptiles, Mammalia, and Birds, may be thus recapitulated:—

In *Reptiles* the cells are large and few. The air has access to the respiratory capillaries only on one surface, viz., that towards the cavity of the cell which they line: and where two cells are contiguous, but separated by a septum, the septum has a capillary web on each of its surfaces.

In *Mammalia*, for the most part, the cells are much multiplied, and where two lie side by side, the septum between them has but one layer of capillaries, which is, in a great measure, common to them both, and aerated on both its surfaces. And here we may remark the reason of the non-isolation of the lobules by areolar tissue in the mammalian lung, except at the borders and thinner parts, where such isolation is necessary for the movements of the lung in respiration. When the lobules are thus isolated, the capillaries on the cell-walls which bound the lobule can have air only on that surface which is towards the cavity of the cells; whereas, when the contiguous lobules are blended by the fusion of the cell-walls which form their exterior, these cell-walls, like the rest, contain but a single respiratory plexus, which is aerated on both its surfaces.

In *Birds* the respiratory capillary plexus is rendered the most perfect possible, both by the omission of the elastic supporting tissue, and also by the vascular plexus being no longer lamellar, but solid, or extended alike in all directions. It is manifest that by this arrangement a given pulmonary space is made to contain the greatest possible quantity of capillary wall, and that this wall is exposed most completely to the action of the air admitted around it.

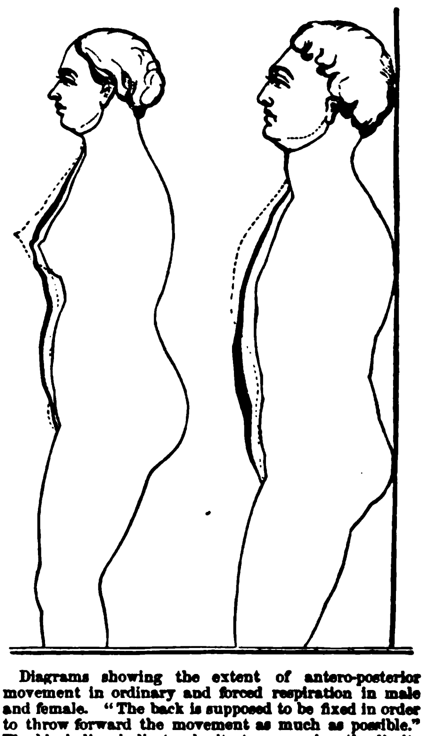
Movements of Respiration.—The thorax is a movable framework composed of a nearly fixed column, the dorsal spine, on which are movably articulated twenty-four ribs, curved and inclined so as to embrace a large conical space, and ending in cartilages, which, with three exceptions on each side (the floating ribs), are joined in front through the medium of a flat piece, the sternum, the inclination of which is downwards and forwards. The upper orifice, embraced by the vertebral column, first ribs and sternum, is closed by a fascia of dense areolar tissue, rendered extremely irregular by the apices of the lungs rising slightly into the neck, and by the various structures—the œsophagus, trachea, great bloodvessels, muscular and other parts—that pass through it. The lower orifice, which is very much larger, is closed by the diaphragm, an arched and sloping musculo-tendinous septum between the thorax and abdomen, through which pass the inferior vena cava, the aorta, and great absorbent trunk, as well as the œsophagus and the pneumogastric and sympathetic nerves. Between the ribs are placed the two layers of intercostal muscles with oblique fibres oppositely crossing, and chiefly on the exterior of the bony framework are added other muscles, which may enlarge or diminish the area of the cavity, and thus act in respiration, but which are, for the most part, subservient to the general muscular movements of the body.

The thorax is capable of enlargement in all its dimensions: in height, depth, width. Its vertical extent is increased by the elevation of the ribs and the widening of the intercostal spaces, but chiefly by the descent of the diaphragm. Its antero-posterior and transverse diameters are increased by the elevation of the ribs, which

'orwards as well as raise the sternum (and the lower end of
›ne usually a little more than the upper, in consequence of the
· length and obliquity of the lower sternal ribs), and which
em to undergo a slight rotation on a line joining their two
ities, by which their middle part is raised and slightly re-
from the median plane of the thorax. These are the princi-
des provided in the mechanism of the thoracic walls for its
ion in breathing. It should be added that during the advance
sternum the arch of the ribs is widened, chiefly by a torsion
r cartilages, and that the elastic rebound of those parts is a
ul agent in expiration.

rved Movements.—All the foregoing modes of enlargement
thorax act in deep inspiration, but in ordinary breathing there
nsiderable differences
ing to sex and age.
ı, an ordinary inspira-
ı attended with very
elevation of the ribs,
re than one-twentieth
nch, according to Dr.
nson's observations;
s, in women, this
ent is very obvious,
ılarly in the upper ribs.
ɔt improbable that the
of this may lie in the
er waist of the female,
g an undue enlarge-
ɔf the upper part of
›rax to compensate for
aller size and less dila-
r of the ample base.
paration of the ribs
dening of the intercos-
ces when the chest is
d, are proved by mea-
nt both in the living
ad. Dr. Hutchinson
de casts of the interior
both states. Dr. Sib-
ides the ribs into three
ı superior set of five,
ely joining the ster-
ın intermediate set of
with conjoint carti-
and an inferior or diaphragmatic set of four with floating car-
. He considers that all, except the upper four in their front
iverge from one another in inspiration, the inferior set the
›ut the lowest of all remaining stationary. Messrs. Beau and

Fig. 209.



Diagrams showing the extent of antero-posterior movement in ordinary and forced respiration in male and female. "The back is supposed to be fixed in order to throw forward the movement as much as possible." The black line indicates, by its two margins, the limits of *ordinary* inspiration and expiration. In *forced inspiration*, the body comes up to the dotted line, while in *forced expiration*, it recedes to the smallest space indicated. From Dr. Hutchinson.

Maissiat* describe three varieties of ordinary respiration: 1. Abdominal, or that chiefly effected by the diaphragm and apparent in the motion of the abdominal walls. This occurs in infants up to the end of the third year, and in males generally. 2. Costo-inferior, or that in which the lower ribs (those of Mr. Sibson's intermediate and inferior sets) are observed to act. This is observed in boys after three, and in men. 3. Costo-superior, or that effected in a considerable degree by the upper ribs. This is observed in females, especially in adults.

Action of Muscles.—The *diaphragm* has an arched form, is highest in front, lowest behind. The fibres pass to a central tendon on which is seated the heart in the pericardium, the lungs resting chiefly on the muscular parts. Its contraction would tighten and then depress both the central tendon and the muscle generally, and would also tend to straighten the curve formed by the fibres as they pass from the spine and ribs to the central tendon. Thus the heart would be lowered a little, but, perhaps, the lungs more, and the area of the pulmonary compartments of the thorax would be much enlarged, for the diaphragm acts at their wide and ample base, where a slight range of vertical movement produces a great effect. In its descent, the diaphragm presses down the abdominal viscera, and bulges the abdominal walls. In expiration, it recedes upwards, being pushed upon by the abdominal walls through the medium of the viscera.

The action of the *intercostal muscles* is less obvious, and had been the subject of much difference of opinion, even before the days of Haller. It may be studied on mechanical principles, and by observation. Hamberger† has given the most elaborate and complete exposition of the mechanical view of the subject, and has illustrated it with diagrams and models. He shows that if two parallel bars (ribs) slope downward from a fixed vertical column (spine) to which they are separately articulated (heads of the ribs) and are kept separate at their opposite ends (as by the sternum), then a contractile force (muscle) acting between them, will raise or depress both bars, according to the direction of its obliquity. If the contractile cord slope downward *from* the column representing the spine (external intercostal fibres), the bars will both be elevated by its contraction, and will carry upwards the sternal element. As they rise, the cord is seen to shorten.

If on the other hand the contractile cord slope downwards towards the vertical column (internal intercostal fibres), then the bars will be both depressed by its contraction. It is obvious that the space between the bars will be widened as they rise towards the horizontal line, and narrowed as they fall. Hence it seems clear, without entering upon the mechanical theorems by which the above results may be proved, that the action of the external and internal intercostals must be antagonistic. That the former must elevate and

* Archiv. Gén. de Méd. t. xv. p. 399.
† Physiologia Medica, Jenæ, 1751, 4to. p. 140, *et seq.*

open out the ribs, the latter depress and approximate them—that, as the fibres of the one are shortened, those of the other must of necessity be lengthened.

It is true that the ribs are curved, and variously flexible, instead of straight and stiff; that their articulations differ from one another, and are nowhere purely ginglymoid, and that other forces besides the intercostal muscles influence their movements.

These considerations, however, do not seem to affect the substantial accuracy of Hamberger's views, so far as relates to the greater number of the ribs, and indeed to all in the posterior region. And Dr. Hutchinson has done well to call attention to them and to illustrate them by new researches. But Dr. Sibson has shown by observations both in man and animals, and in the latter especially, by a series of careful experiments upon the actual movements of the thoracic walls and their muscles, exposed during life, that the external intercostals are not everywhere inspiratory, nor the internal ones expiratory. For, in the upper two or three spaces in front, the internal, as well as the external intercostal fibres, contract and approximate the ribs. Those fibres, also of the internal intercostals, which pass between the cartilages of the ribs, contract during inspiration, and correspond with the internal intercostals of the sternal ribs of birds, which are powerfully inspiratory, and slope downwards and backwards from the sternum. These may have their action explained by Hamberger's views, if the sternum be regarded as giving the fulcrum instead of the vertebral column. Again, the lowest external intercostal lengthens in inspiration, and is an expiratory muscle, the eleventh rib in inspiration rising from the twelfth, which is stationary.*

On the whole we may conclude, that in inspiration, the upper ribs rise by the action of the scaleni—that the rest of the ribs in their hinder part rise and open out by the action chiefly of the external intercostals; while in front the intercostal spaces are narrowed above by the rise of the second, third, and fourth ribs towards the first, and at the same time widened midway and below, the flexibility of the costal cartilages having much to do with this latter movement. It may, also, be regarded as certain that the internal intercostals, except in front, are muscles of expiration, and approximate the ribs.

* On February 26, 1851, Dr. Sibson exposed the intercostal muscles in a dog under chloroform, when we noted the following as facts: 1. The lower fibres of the serratus magnus contract during inspiration; the upper fibres lengthen. 2. The first five intercostal spaces diminish *decreasingly* during inspiration. 3. The seventh, eighth, and ninth ribs diverge *increasingly* from the seventh to the ninth, and the tenth, eleventh, and twelfth in a less degree. 4. The twelfth rib is stationary. 5. The first external intercostal muscle shortens, the lowest lengthens, during inspiration. 6. The first and second internal intercostal muscles, in front, shorten during inspiration; the third, also, in a very slight degree. 7. The sixth internal intercostal elongates during inspiration, and the ninth also, but in a greater degree. 8. The eleventh anterior external intercostal of the diaphragmatic ribs shortens during inspiration. 9. Behind, the tenth external intercostal shortens, the tenth internal lengthens, during inspiration.

Dr. Sibson has well pointed out that the forces which expand the thorax act, in a great degree, in a separate and independent manner on its several parts; that the lower region, and the lower lobes of the lungs which fill it, are enlarged by the diaphragm and lower external intercostals, while the upper region expands under the influence of the scaleni, its external intercostals, and (in front) its internal intercostals. A variety of morbid conditions of the lungs, where the expansibility of one or more lobes is modified, illustrates this observation, for one side of the chest may be observed to expand without the other, or a portion of one side without the rest. How important this amount of independence of the parts of the chest is to the preservation of life, under accident or disease, needs hardly be explained.

In addition to the muscles now mentioned, the *levatores costarum*, *cervicalis ascendens*, and *serratus posticus superior* are probably muscles of ordinary inspiration; and those of the abdominal wall, with the *levator ani*, of expiration; the latter action being aided by the elasticity of the ribs and their cartilages, and by the resilience of the elastic tissue entering so largely into the composition of the lungs themselves. This resilience (which Dr. Carson showed to be sufficient in sheep and dogs to balance a column of water from one to one foot and a half in height) occasions the collapse of the lungs when the pleural cavity is accidentally opened, as sometimes by wound of the parietes. In such cases the air passes in and out of the thorax through the wound in respiration, and the air previously in the lung is expelled through the glottis by the elastic force of the pleura and walls of the air-passages and cells. If the lung also be wounded, the air may pass into the pleural sac from the air-passages under the same resilient force, and be thence pumped by the expiratory forces through the wound in the parietes into the areolar tissue of the body, as so often happens in the case of fractures of the ribs.

Extraordinary Muscles of Respiration.—In voluntary deep breathing, or when (as in asthma) the head, neck, and upper extremities become fixed points for the muscles passing between them and the thorax, the lower part of the serratus magnus, the pectorales, the subclavii, with the sterno-mastoidei, trapezii, and some others, aid in dilating the chest. Some difference exists among the most recent authors as to the share particular muscles take in the movements of respiration; and this is not surprising when we consider the complexity of the problem, the difficulty of determining the fixed points, or of observing the muscles in separate action. In *forced expiration*, the triangulares sterni, the serrati postici inferiores, sacro-lumbales, latissimi dorsi, with their accessories as high as the highest costal insertion, probably help to depress and approximate the ribs.

Power of the Respiratory Muscles.—Dr. Hutchinson has lately made numerous experiments on this subject, and his results and those of Valentin and Mendelssohn agree. He finds as the average of 1,500 trials that the expiratory power exceeds the inspiratory by

hird; that men of 5 feet 7 or 8 inches have the greatest inspi-
y power, and should on an average raise a column of mercury
inches; while, above this, the strength gradually decreases as
ature increases, so that a man of 6 feet raises a column of only two
s and a half: also, that occupation or mode of life serves much
odify the relation which the inspiratory and expiratory powers
to each other. Thus, wrestlers, boxers, and others, accustomed
ploy the extraordinary muscles of respiration, in rendering the
x a fixed point from which other muscles might act, were found
ve an unusual power of expiration. In one wrestler he found
xpiratory power exceed nearly four times that of the natural
atory power. Valentin, in six experiments on young adult
, found the force exerted in *ordinary*, *tranquil* inspiration and
ation to be from about one-seventh to three-sevenths of an inch
rcury. Dr. Hutchinson calculates that a man who raises three
s of mercury by an effort of inspiration exerts a force equal
000 lbs. In one man he found the mercury raised to such a
t (seven inches) as to indicate a force of 2,200 lbs., or nearly

ien the capacity of the thorax is augmented, the air in the lungs
ids so as to keep them in contact with the walls, and the ex-
l air enters by the trachea to restore the equilibrium. When
ilating force ceases, the walls of the chest contract upon the
, and expel a portion of the air, the lungs themselves conspir-

e of the Trachealis Muscle.—That the trachealis in contracting
diminish the area of the trachea and bronchia is obvious from
rangement no less than from experiment. Dr. Williams found
he lungs taken from an animal just killed manifestly contracted
the stimulus of galvanism. The fibres are allied to those of
ucts of glands, and of the bloodvessels, and are consequently
bly incapable of coinciding in action with the muscles of respi-
. It further seems impossible to assign an object to any
altic action which might be attributed to them. We are dis-
to consider that the trachealis muscle contracts and dilates the
bes slowly, in relation to the activity of the respiratory func-
t different times of the day, or under other modifying circum-
es. Its contraction would tend to limit the quantity of air
mitted in a given time, or would quicken its passage. It is in
obability contracted spasmodically in spasmodic asthma, and in
rly stages of bronchitis. If it contracts during the sensation
precedes and accompanies coughing, this would facilitate the
sion of mucus by quickening the expelled current of air.

citation of the Respiratory Movements.—We have already re-
l to the share taken by the nerves in respiration. The respi-
y acts are essentially involuntary, and unconsciously performed,
ugh we have a limited power of checking or accelerating them,
rying their rhythm or force, and can become aware of them by
ort of attention. After holding the breath for fifteen or twenty

seconds during ordinary respiration, or forty seconds after a deep inspiration, there arises an insupportable sensation over the whole chest, concentrated under the sternum, and no effort can maintain the interruption of the respiratory acts. This urgent sensation of want of breath, when carried to its full extent by any mechanical impediment to the aeration of the blood, is one of the most painful and oppressive kind, and is referable to the pulmonary plexuses distributed on the bronchia, and perhaps on the walls of the lobular passages and cells. The impression made on these peripheral nerves by the absence of oxygen, and the undue presence of carbonic acid in the air in contact with them, is propagated to the spinal cord and medulla oblongata by the sympathetic and vagus, and there excites those combined actions of the muscles of inspiration which lead to the renewal of the air; and it may be fairly concluded that the ordinary motions of respiration depend on the same circle of nervous actions, which thus, voluntarily arrested, become apparent by their accumulated force. The muscular actions of expiration, which seem to follow so evenly on those of inspiration, are probably due, in part at least, to the stimulus of elongation of their fibres. When the ribs diverge, the fibres of the internal intercostals, except in front, are extended.

Frequency of Respirations and Ratio to the Pulse.—The number of respirations per minute in healthy adults is from eighteen to twenty; but, according to Dr. Hutchinson's observations on more than 1,700 persons (when sitting), the range in health may be from six to forty, though most persons breathe from sixteen to twenty-four times per minute. The proportion which the respirations bear to the beats of the heart is liable to much variation, but is in general not far from that of one to four. Dr. Guy has shown that the respirations are rather more frequent in the evening than in the morning, whereas the pulse is rather slower. He has also discovered that the proportion between the respirations and pulsations is much deranged by changes of posture, probably by these modifying the expansion of the lungs at each inspiration, without inducing any corresponding change in the transmission of the blood.

Aerial Capacity of the Lungs, and Amount of Air Breathed.—When the lungs have been emptied as much as possible of air, by a forced expiration, they still contain a residual quantity, which may be estimated at about forty cubic inches. The mechanical conditions under which the organs are placed do not allow of their expelling this remnant. If, now, the deepest possible inspiration be taken, it is found that they are capable of inhaling a further quantity, varying much in different persons, but on an average about 240 cubic inches, which, with the former residual quantity, make a sum of 280 cubic inches as the full capacity of the lungs of a person of good height (5 feet 8 inches). But in ordinary breathing, the lungs are neither very empty nor very full—they maintain a middle condition, and their range of movement in natural or ordinary respiration is only sufficient to pump in and out a quantity of air equal to about

cubic inches. From the best observations, it may be concluded ıt a person whose full capacity is 280 cubic inches, contains in his ıgs, after an ordinary expiration, about 110 cubic inches; and er an ordinary inspiration, about 140 cubic inches, a quantity ich he is enabled to double by a *full* inspiration. Thus rather re than one-fifth of the ordinary contents of the lungs are expelled each expiration, and again renewed by inspiration.

Dr. Hutchinson, by means of a gasometer, which he terms a *spiroter*, has examined a large number of persons with reference to ir power of taking air into the lungs. The person first inspires the full extent, and then breathes into the instrument as much air he can, and it results that the *height* of the individuals has much do with their respiratory range. Thus, while on an average a rson of 5 feet breathes 174 cubic inches, one of 5 feet 1 inch will athe 182 cubic inches, and for every inch of height up to 6 feet, ll breathe about 8 cubic inches additional. Weight has much less luence than height, but tends to diminish the respiratory power ıen beyond a certain limit. In males of the same height, the piratory range (*vital capacity* of Hutchinson) increases from 15 35 years of age; but from 35 to 65 it decreases nearly $1\frac{1}{2}$ cubic hes per year. Bourgery agrees nearly with this: he states that re air can be inspired at thirty than at any other age, and that in l persons the range is very limited. Bourgery calculates that a ild of ten years of age, with a weight three times less than that a man of eighty, has a respiratory power eight times greater. is is due to the great difference there is in the range of the respitory movements. The old man being able to increase the amount athed by less than a half, while the child may increase it nearly rteenfold. Herbst has shown that the capacity of the lungs is ıch smaller in the female than in the male.

Having now considered the anatomy of the respiratory organs, d the movements which regulate the supply of air, we may proceed consider the changes which occur in the air during its sojourn in ntact with the respiratory surface, and also the corresponding anges in the blood circulated there.

Changes in the Respired Air.—The air consists of a mixture of ygen and nitrogen, in the respective proportions of about 20.81 d 79.19 in 100 parts by volume, with the addition of a very minute rtion of carbonic acid gas, not exceeding one part by volume in 000. It contains watery vapour in variable quantity, according to nperature and other circumstances; and also non-estimable quanies of other gaseous and volatile substances, of no account in reion to the respiratory function. In air that has been breathed, e temperature is found to have assumed nearly or quite that of the od, the quantity of moisture has nearly reached the point of satution, the proportion of oxygen has diminished, and that of carbonic id has increased, while that of nitrogen has slightly increased, or s undergone little change. A small quantity of animal matter s also been received from the air-passages, as is proved by the

brown colour assumed by sulphuric acid, through which the respired air is made to pass.

Aqueous Vapour Exhaled.—It results from the most careful experiments, amongst which may be mentioned those of Valentin and Brunner, and of Moleschott, that the air expired is usually nearly saturated with moisture, and that the quantity of water thus escaping from the system in twenty-four hours, may be estimated in temperate climates at from twelve to twenty ounces. It is, of course, impossible to ascertain, nor is it important, how much of this quantity is derived from the respiratory surface, strictly so called, and how much from the moist and vascular surfaces of the nasal, pharyngeal, and bronchial passages.

Exhalation of Carbonic Acid by the Lungs.—It is easy to show that carbonic acid gas is exhaled from the lungs, by breathing into lime-water, which thus becomes turbid by the formation of insoluble carbonate of lime; or into a phial, where a taper is then at once extinguished.

In 100 parts by volume of expired air (as an average of many experiments),

		Carbonic Acid.
Coathupe .	found . . .	. 4.02.
Valentin and Brunner .	" . . .	. 4.38.
Vierordt .	" . . .	. 4.33.
Thomson .	" . . .	. 4.16.

The general average of the results of Valentin and Brunner, and Vierordt, all of which were performed on adult males, may be accepted for that age and sex, viz.: 4.35 parts of carbonic acid in 100 parts of expired air; or deducting the small quantity of carbonic acid contained in the air when inspired, we may conclude that 4.30 parts per cent. by volume of that gas are derived from the lungs at each ordinary expiration. Taking, as before, 30 cubic inches as the volume of each expiration, the actual quantity of carbonic acid in each will be 1.29 cubic inches=about 23 cubic inches per minute=about 1,393 cubic inches per hour=about 27,864 cubic inches, or 16.1 cubic feet per day. In this last quantity of carbonic acid, there are about seven and a half ounces by weight of carbon.

A great variety of circumstances no doubt modify the activity with which carbonic acid is formed in the system, and eliminated from it; some of these are very worthy of notice. *Digestion* has been observed to be attended with an increased exhalation of it in many of the lower animals; and Scharling, Valentin, and Vierordt have recently noted the same fact with great accuracy in Man. Thus, one hour after a midday meal, Vierordt found that his pulse was quickened by 15, his respiration by 1, the volume of the expired air was slightly increased, nearly 50 per cent. more of air, and $2\frac{1}{2}$ cubic inches more of carbonic acid were expired in one minute, and the percentage of carbonic acid in the expired air was also augmented in a very trifling degree. If the meal were omitted, these results

did not occur. On the other hand, *fasting*, especially if prolonged, diminishes the exhalation.

Particular substances taken into the blood exert a very remarkable influence upon the development of carbonic acid in the system. Dr. Prout long since observed a considerable diminution under alcohol, particularly if taken on an empty stomach; and his conclusions have been fully confirmed by Vierordt and Bocker. The former found that, having taken more than half a bottle of wine, the carbonic acid fell in a quarter of an hour from 4.54 to 4.01 per cent. of the expired air; *i. e.*, by about one-ninth of its whole quantity; and this lasted for two hours. In addition to this, the latter author found that, under the same influence, the whole constituents of the urine are diminished in amount. Dr. Prout states that a dose of strong tea likewise lessens the exhalation of carbonic acid.

Since the introduction of ether and chloroform as anæsthetics in the practice of surgery, their mode of action has been much investigated, and by no one more extensively or more accurately than by Dr. Snow, who has, among other matters, turned his attention to the amount of carbonic acid gas passing from the lungs under their use. A small animal being placed in a jar, in which the air could be circulated in connection with a receptacle containing solution of potash, for absorbing the carbonic acid, the quantity of this gas expired during periods of half an hour was estimated, when the animal breathed firstly air, and afterwards air mixed with certain quantities of the vapour of chloroform. The results were such as the following: A dog, eight pounds in weight, exhaled in air 10.1 grains of carbonic acid gas; in air mingled with 36 grains of chloroform vapour, only 4.8 grains. A half-grown cat expired in air 5.7 grains of carbonic acid gas; in air mingled with 20 grains of chloroform vapour, only 2.0 grains. And this diminution was observed, on this and other occasions, to be in spite of increased muscular efforts on the first introduction of the chloroform, such as are known to have a tendency to augment the excretion of carbonic acid.

Exercise increases the exhalation of carbonic acid, and doubtless also the formation of it in the tissues. Mr. Newport observed that the generation of carbonic acid from bees, when at rest, did not exceed that from cold-blooded animals; but when in active movement, it was more energetic than in any other animals; and other experimenters have produced analogous results. With more precision, and in the case of the human adult, Vierordt shows that, during moderate exercise, there is an average increase per minute of 19 cubic inches in the expired air, and of 1 cubic inch in the expired carbonic acid.

The *temperature of the surrounding medium* was shown by Seguin and Lavoisier to have an important influence on the exhalation of carbonic acid, and their results were corroborated by those of Crawford. Vierordt has recently examined this point also. In numerous experiments upon himself, at temperatures of which the average was 47° Fahrenheit, he expired 18.25 cubic inches of carbonic acid per

rbonic acid in the expired air is less. Thus the percentage of is gas bears a certain proportion to the frequency of the respirations, supposing their bulk to remain the same.

If the respiratory movements are suspended for a short time, the rcentage of carbonic acid in the expired air becomes increased. he total quantity expired is, on the other hand, somewhat diminished; showing that this increased percentage, in a given quantity air, does not compensate for the smaller proportion of air entering e lungs under these circumstances.

Allen and Pepys found, that when the same air was breathed ore than once, the proportion of carbonic acid underwent a conlerable increase. Air breathed nine or ten times, contained 9.5 r cent. of carbonic acid; but if the air was breathed over again often as possible, the percentage of this gas could not be increased above 10. Mr. Coathupe obtained as much as 12.75 per nt. of carbonic acid from air in which animals had been placed til they were suffocated.

The percentage of carbonic acid varies also at different periods of me during the same respiration. By taking the average of twentyne experiments, Vierordt found, that while the proportion of carnic acid in the entire expiration amounted to 4.48 per cent., the st half contained 3.72, and the last half 5.44 per cent. It has en estimated, that the air from the air-cells contains as much as .88 per cent. of carbonic acid, or about 1.3 per cent. more than e air of an ordinary expiration.

Amount of Oxygen Inhaled.—The quantity of oxygen introduced to the system in respiration, is always greater than is required to rm the amount of carbonic acid eliminated during this process. his surplus quantity no doubt is employed in oxidizing other subances in the organism besides the carbon; such, for instance, as lphur and phosphorus, which are eliminated in the urine in the rm of sulphuric and phosphoric acids. Valentin and Brunner und that the proportions of these gases approximated very closely their diffusive volumes; for the quantities obtained by direct experiment, and by calculation, differed very slightly. Oxygen being e lighter gas, a larger quantity is required to replace the carbonic cid; 81 parts of the latter will require 95 of the former to replace according to Graham's law, that the diffusion volume of different ses varies inversely as the square root of the density, or about one olume of absorbed oxygen corresponds to .85 of exhaled carbonic cid. The experiments of Dulong and Despretz, as well as those of egnault and Reiset, have, however, shown that this relation is by o means constant.

From the above considerations, it is evident that the respiratory hanges cannot be efficiently carried on, unless a certain proportion f air be assigned to each individual living in a confined space. For f the cubic capacity of the apartment be below a certain standard, he air becomes so contaminated by the increased quantity of caronic acid expired, as to produce a highly deleterious effect upon the ealth.

Probably between four and five hundred cubic feet of air pass through the lungs daily, and in the same period, about twenty-three cubic feet of oxygen gas are absorbed. The size of an apartment, therefore, in which persons are confined should be such, and its ventilation should be so arranged, that each individual may be supplied with the above quantity of pure air as a minimum. The cubic capacity of such rooms should not be less than 800 cubic feet for each person inhabiting them. Leblanc found, that in the Chamber of Deputies in Paris, each individual was supplied with only from 353 to 706 cubic feet of air per hour; and in the air issuing from the apartment, he found from 2 to 4 of carbonic acid in 1000 parts by weight. This proportion of fresh air was probably too small, since it has been found that 1 per cent. of carbonic acid produces a deleterious effect upon the system when breathed for a long time continuously. In the Model Prison, Pentonville, from 1800 to 2700 cubic feet of fresh air pass into each cell per hour. In hospitals, the number of patients in each ward should be so arranged, that not less than from 800 to 1000 cubic feet should be assigned to each. In the new King's College Hospital, each patient has from 1850 to 2500 cubic feet of air.

Dr. Snow has shown that the bad effects of air deteriorated by respiration, are due not only to the increased quantity of carbonic acid which it contains, but also to the diminution of its oxygen. From his experiments upon animals he has been led to conclude, "that 5 or 6 per cent. by volume of carbonic acid cannot exist in the air without danger to life, and that less than half this amount will soon be fatal, when it is formed at the expense of the oxygen of the air."

Exhalation of Nitrogen.—MM. Regnault and Reiset have shown that an extremely small quantity of nitrogen is constantly exhaled, its proportion varying according to the nature of the food. After prolonged fasting, this gas, however, appears to be absorbed, instead of being exhaled. Barral found that the quantity of nitrogen exhaled from the lungs of man, was about $\frac{1}{100}$th of the amount of carbonic acid removed in the same time. It must also be observed, that a very small proportion of nitrogen is constantly being expired in the form of ammonia.

Changes in the Blood resulting from Respiration.—Dark venous blood in its passage through the capillary vessels of the lungs assumes the bright red colour characteristic of arterial blood. This change, as is well known, depends upon the removal of carbonic acid gas and the absorption of oxygen. Magnus showed that venous blood contained 25 per cent. of its volume of carbonic acid, and 5 per cent. of oxygen; and that arterial blood, on the other hand, contained as much as 10 per cent. of its volume of oxygen, and only 23 per cent. of carbonic acid. The seat of this change is clearly in the red blood corpuscles; but its precise nature has not yet been satisfactorily determined. It has been ascribed to a chemical change taking place in the coloured constituent of the blood globule (page 640), but later researches render it probable that it is, at least in some measure, due

is a physical alteration. Henle was the first observer who referred the change of colour in the blood corpuscle to a change in its form.

Scherer states that the blood corpuscles of venous blood are nearly spherical, and their walls thin and transparent, a condition which causes them to transmit light freely. On the other hand, the corpuscles of arterial blood are bi-concave, their walls thicker, and they reflect light more readily, which is considered to account for the brighter colour of arterial blood. Harless has even been able to measure the difference in size between the blood corpuscles of arterial and venous blood of the frog.

Magnus proved that serum would dissolve twice as much carbonic acid as an equal quantity of pure water, a power which Liebig attributed to the amount of phosphate of soda contained in blood serum.

Of the gases existing in the blood, a very small proportion only is in chemical combination with any of the constituents of that fluid, but the greater quantity is held in solution in a free and uncombined state. This is readily proved by passing a current of hydrogen gas through some defibrinated blood placed in a bottle to which tubes are adapted. The hydrogen takes the place of the gas previously held in solution and the latter escape; and by causing them to pass through lime-water, evidence of the presence of much carbonic acid is at once obtained by the formation of a precipitate of carbonate of lime. If the carbonic acid had existed in a state of chemical combination, we should not have been able to obtain evidence of its presence by this process. Besides much carbonic acid, oxygen, and a little nitrogen, are held in solution in blood.

With reference to the oxygen, it cannot be doubted that part is in chemical combination with the constituents of the blood corpuscle, and part in a state of simple solution.

The chief agents in effecting the absorption of gases in the blood are undoubtedly the blood corpuscles, for it has been clearly proved by Davy and others, that defibrinated blood possesses the power of absorbing gases in a greater degree than blood serum. Magnus found that blood was capable of absorbing 1½ times its volume of carbonic acid gas.

From the researches of Professor Lehmann upon the crystallizable contents of the blood corpuscle, originally discovered by Otto Funke, we are led to conclude that the colouring matter of the blood is chemically affected by oxygen and carbonic acid gases.

Lehmann has shown, that if oxygen is allowed to pass through defibrinated blood slowly for fifteen minutes, and is followed by the transmission of a current of carbonic acid for five minutes under the influence of light, these crystals are formed in larger quantity, and more rapidly, than if the carbonic acid is passed through the blood first. These crystals are composed of a definite chemical compound; and there can be little doubt that the influences which the gases exert upon its crystallizing properties are of a chemical nature.*

* For much interesting matter upon the subject of blood-crystallization, the reader is referred to Lehmann's *Physiological Chemistry*, 1853, translated by Dr. Day, Cavendish Society, vol. iii.

It was formerly supposed that the oxygen of the air combined with the carbon of the venous blood in the pulmonary capillaries, and that the carbonic acid eliminated from the system was formed at the pulmonary surface; but later researches have shown that this gas exists preformed in the blood, and is therefore only *exhaled* from the fluid contained in the vessels of the lungs, a view which was first advocated by Lagrange and Hassenfratz in 1791. It has been found that animals will give up carbonic acid when placed in atmospheres which do not contain any oxygen, a fact which could not be accounted for upon the supposition that this gas was formed by the combination taking place in the pulmonary organ. Again, the presence of both free oxygen and carbonic acid can be proved in the arterial and venous blood. Moreover, blood may be caused to absorb, or to give up, these gases after it has been removed from the body.

All the tissues of the body contain a small quantity of dissolved gases; and carbonic acid can be detected in all the animal fluids, even in the urine.

Frogs' muscles, carefully deprived of nerves and vessels, will give out carbonic acid if placed in an atmosphere of oxygen gas, and it has been shown by G. Liebig, that the muscles continue to absorb oxygen, and to exhale carbonic acid, as long as their power of contractility lasts, and that they retain their contractile power for a much longer period in an atmosphere of oxygen gas than in one of hydrogen, nitrogen, etc. The careful observations of Lehmann upon the respiration of insects (in which class the air is directly carried to the elements of the tissues by the tracheæ), tend still further to prove the truth of this view. We may therefore conclude, that the oxygen of the air is carried by the blood to the ultimate elements of the tissues, and that here chemical combination takes place and carbonic acid is produced; the carbonic acid being then transmitted to the lungs in solution in the venous blood, and there exhaled.

Quantity of Carbon removed from the Body.—The estimation of the amount of carbon eliminated from the organism in a given time is a matter of great difficulty, and the results of the experiments of observers present wide differences. Allen and Pepys calculated the daily quantity at rather more than 11 oz. troy, while Mr. Coathupe estimated it at only 4.97 ounces, and Scharling at 7.382 ounces.

The method employed by Liebig consisted in subtracting the total quantity of carbon in the feces and urine from that present in the food; the remainder represented the quantity excreted in the breath in the form of carbonic acid. From these data, Liebig calculates that an adult male, taking moderate exercise, loses 13.9 ounces of carbon daily from the lungs and skin. In order to convert this large quantity of carbon into carbonic acid, 37 ounces of oxygen must be absorbed during the same period by the lungs and skin; but this estimate is doubtless too high. Andral and Gavarret estimated the carbon at nine ounces.

According to the recent accurate investigations of Scharling, a powerful adult man exhales in the course of twenty-four hours about

10.6 oz. of carbonic acid, which corresponds to 8.84 oz. of carbon, and this we may look upon as a correct estimate.

Some very accurate experiments upon this subject have been made by M. Barral upon himself during summer and winter. The great difference noticed in the quantity of carbon exhaled at different periods of the year may, to some extent, explain the discrepancies in the results of various observers—

	Weight of body. lbs.	Carbon in food. grs.	Carbon excreted. In feces. grs.	In urine. grs.	Exhaled. grs.
In Summer	104.5	5654.1	286.2	234.6	5183.3
In Winter	"	4090.0	187.4	211.5	3741.1

About 10.8 oz. troy of carbon, therefore, passed off daily in the form of carbonic acid in winter, and 7.8 oz. in summer. The amount of carbon eliminated by respiration will also be influenced by the quantity and nature of the food, and by other circumstances, which have been previously adverted to.

Theory of Respiration.—By the interchange of gases in the lungs, the venous blood becomes of the bright scarlet colour characteristic of arterial blood. The oxygen and carbonic acid both permeate the delicate, moist, limitary membrane of the air-cells at the same time, but in opposite directions.

The oxygen, having passed through the capillary walls, is held in solution in the blood; a small part entering into chemical combination with the contents of the blood corpuscle, and to a less degree with some of the constituents of the serum.

A portion of the oxygen not improbably acts directly upon certain substances contained in the circulating blood, and contributes to the formation of carbonic acid. In this way some of the elements of the food lately introduced into the blood may become decomposed, and their carbon removed in the form of carbonic acid. The greater portion of the oxygen is no doubt carried to the capillaries, and much of it then leaving the blood, and passing through the capillary walls, becomes dissolved by the intercellular fluid, in obedience to the same physical laws by which it was absorbed. At the same time, the carbonic acid formed in the interstices of the tissues, and dissolved by the fluid which moistens their ultimate elements, leaves this latter to enter the blood, from which the oxygen has just been removed, and causes it to assume the colour of venous blood.

Here, then, are two sources of carbonic acid—one resulting from the action of the oxygen upon certain elements recently introduced in the food, giving rise to the production of a certain amount of animal heat, and the other depending upon the union of the oxygen with the carbon of those substances which are produced in the disintegration of tissues during the performance of their functions; in this combination also, heat is developed.

In purely carnivorous animals, the greater portion of the carbonic acid results from the disintegration of the muscular and nervous tissues; while, in the herbivora, much of the food, rich in carbon and poor in nitrogen, is at once converted into carbonic acid.

Although the action of the oxygen upon the carbon of the compounds, from which the carbonic acid is formed, is a strictly chemical process, the application of this oxygen to the substance to be decomposed, and the removal of the resulting carbonic acid, are dependent solely upon the physical relations which these gases bear to each other, to the membrane through which they pass, and to the fluids in which they are dissolved.

The blood, loaded with carbonic acid, at length returns to the respiratory surface, where it parts with this gas and absorbs oxygen in obedience to the physical laws above referred to.

More oxygen is usually absorbed than is necessary to convert the carbon into carbonic acid. This is required for the oxidation of other elements, as sulphur and phosphorus, by which compounds are produced which are eliminated by other emunctories.

The amount of oxygen inhaled will depend in great measure upon the quantity and nature of the food, and upon the activity of the vital functions, and is intimately associated with the production of animal heat, as will appear in the next chapter.

It has been shown that the activity of the respiratory function is materially influenced by various external and internal conditions. Temperature, a dry or moist state of the atmosphere, the period of the day, the digestive process, rest, exercise, etc., all exert an influence on the amount of oxygen inhaled and of carbonic acid exhaled. These are points which must be borne in mind by the careful practitioner in the treatment of such diseases as phthisis, pneumonia, emphysema, and the like.

Respiration is, therefore, partly a physical and partly a chemical process; chemical as far as regards the results; physical, with reference to the means by which these results are produced. The introduction of the restorative oxygen, and the removal of the deleterious carbonic acid, are effected solely by a physical process; while the formation of the carbonic acid is essentially a chemical process, and in its production many complicated chemical decompositions take place.

The great objects of respiration are, first, the introduction of oxygen, by which the products resulting from the disintegration of tissues are converted into compounds, which are easily eliminated from the body by the different organs of secretion; and, secondly, the removal of the most important and most destructive of these, carbonic acid, at the pulmonary surface.

Upon the subjects discussed in the present chapter, reference may be made to the following works: Article "Respiration," by Dr. John Reid, Cyclopædia of Anatomy and Physiology; "Thorax," by Dr. Hutchinson; Physiological, Anatomical, and Pathological Researches, by Dr. John Reid; Recherches sur la Structure intime du Poumon. Rossignol, Bruxelles, 1846. The following systematic works: Müller's Physiology; Bostock's System of Physiology; Principles of Human Physiology, by Dr. Carpenter.

On the Mechanism of Respiration.—Dr. Sibson, Phil. Trans., 1846; Med.-Chir. Trans., vol. xxxi.; Dr. Hutchinson, Med.-Chir. Trans., vol. xxix.

On the Chemistry of Respiration.—M. Barral, Ann. de Chim. et Phys., tom. xxv.; Messrs. Regnault and Reiset, Annales de Chimie et de Physique, 1849; Comptes Rendus, 1846; Lehmann's Physiological Chemistry, translated by Dr. Day, Cavendish Society, 1851–4.

CHAPTER XXX.

ON ANIMAL HEAT.—DEVELOPMENT OF HEAT IN PLANTS.—DEVELOPMENT OF HEAT IN ANIMALS.—TEMPERATURE OF THE HUMAN BODY. INFLUENCE OF EXERCISE, SLEEP, AGE, CLIMATE AND SEASONS, FOOD AND DISEASE UPON THE DEVELOPMENT OF HEAT.—HIBERNATION.—THEORY OF ANIMAL HEAT.—INFLUENCF OF THE NERVOUS SYSTEM. BERNARD'S RESEARCHES.

THE chemical changes which are continually taking place in animals, and, at least under some circumstances, in plants, are accompanied with the development of a certain amount of heat. The elevation of temperature may be so slight as to elude the ordinary means of observation; and although the sensible temperature of the organized body is very slightly higher than that of the medium in which it is placed, the quantity of heat set free in a given time may be considerable. This development of heat seems to result from the action of the oxygen upon the combustible elements of the food, and in a less degree upon those of the tissues. The chemical combination in which the largest amount of heat is disengaged in the higher animals, and upon which their high temperature seems to depend, is that of carbon and oxygen, resulting in the production of carbonic acid.

Whenever oxygen combines with carbon, hydrogen, phosphorus, sulphur, etc., or with a metal, heat is developed in an amount exactly proportioned to the quantity of substance consumed. The sensible temperature produced varies, however, with the intensity and rapidity of the chemical action. When the action is intense, the temperature rises very rapidly, and may reach a very high degree for a short time. If, on the other hand, the action is slow, the temperature may be scarcely elevated above that of the surrounding medium; but this slight elevation may continue for a considerable time. The *quantity* of heat developed in the two cases, however, is precisely the same.

Development of Heat in Plants.—Heat is developed by the seeds of plants during germination; and at the same time oxygen is removed from the air, and carbonic acid evolved. Buds, flowers, and ripening fruits also evolve a certain quantity of heat.

M. Hubert, in the Isle of France, encircled a thermometer with twelve spikes of the *arum cordifolium*, and found it rise to 121° F., the temperature of the external air being 66°. During the process of flowering, the spathe of the *arum maculatum* consumed in 24 hours five times its volume of oxygen derived from the surrounding atmosphere, the termination of the spadix 30 times, and the sexual apparatus 132 times its volume, in the same period. In these experiments it was found, that if the plant was protected from the influence of the surrounding air, the development of heat ceased.

In the germination of seeds, the starch is converted into gum or dextrine, and ultimately into sugar. The sugar then disappears while oxygen is absorbed from the air, and carbonic acid evolved. The temperature at the same time rises.

In these examples, the disappearance of the starch and saccharine matters from the plant, the absorption of oxygen, the formation of carbonic acid, and the development of heat are all manifestly connected. A corresponding series of phenomena attends the development of heat in animals.

Development of Heat in Animals.—It is to be observed in the first place, that as all animals give out carbonic acid in their respiration, so all develop heat, whether they are called *cold-blooded* (reptiles and all below them), or *warm-blooded* (mammalia and birds). The cold-blooded animals are those which develop so little heat, form and give out so little carbonic acid, that they are unable to maintain a temperature much removed from that of the medium in which they live; and their circulatory and breathing organs are entirely accordant with this feeble calorifacient power. Dr. John Davy, who has made a number of valuable and exact observations on this subject, found that when the average temperature around was 79.7° F., that of reptiles was only 82°, and that of fishes nearly the same. In the case of insects, crustacea, and mollusca, there is even a closer correspondence with the temperature of the circumambient medium. Insects, however, especially when housed in communities, so that their heat is not rapidly dissipated, have shown a rise of 20° F. above the outward air—provided they were in a state of active movement. On this point, the observations of Mr. Newport are very valuable. On the other hand, warm-blooded animals (birds and mammalia) are those in which nutrition with all its attendant accessory functions, assimilation, circulation, respiration, the supply of food and of oxygen, the formation and disengagement of carbonic acid are most active and energetic. These have a nearly uniform temperature within the limits of 96° and 111° F., the mammalia having the lower and birds the higher, in strict accordance with the above-mentioned circumstances. A bird, for its weight, consumes much more oxygen, and sets free much more carbonic acid, while it maintains in the same medium a higher temperature than a mammal. Finally, some degree of warmth is evolved by the egg in its development during incubation. In this process, oxygen is absorbed, and carbonic acid exhaled through the calcareous envelope.

The amount of heat developed in the animal organism depends very much upon the nature and quantity of the food. The carbon of the food in its slowly effected union with oxygen within the organism, gives out probably as much heat as if the same quantity were burnt in oxygen gas. The development of animal heat will, therefore, in great measure depend upon the activity of the functions of respiration and circulation.

The greater part of the oxygen which an adult consumes in the twenty-four hours, instead of remaining in the body, thereby increases its weight, unites with carbon and hydrogen, and is removed

e form of carbonic acid and water. The remainder enters into ination with other elements, and compounds are formed which emoved by the excreting glands. In these combinations a large nt of heat is developed, ranging in amount according to the itions before referred to.

mperature of the Human Body.—The heat of the interior of ody at those parts which are most accessible to our instruments easurement, as, for instance in the axilla, within the mouth or m, is found to be about 97° or 99° F.; more frequently the r. The temperature is, however, liable to variation according rcumstances, which modify the amount of heat generated within ody or the rapidity of its loss. Independently of this, however, ; differences have been found to exist in the temperature of ent parts, according to the rate of their cooling, their vascu- y, distance from the centre of circulation, etc. A good idea of will be derived from the following Table of Dr. Edwards. He ined a strong man, at rest, in July, the air being at 71° F., found

Mouth and rectum	102°
Hands	99°.5
Axillæ and groin	99°
Cheeks	96°
Feet	96°
Skin of Epigastrium	95°

e best experiments on the temperature of internal parts, are of MM. Becquerel and Breschet, who employed a thermo- ric apparatus, consisting of two wires of different metals, red together, and having their free ends brought into communi- n with an excellent thermo-electric multiplier, with an index to 10ths of a degree. The wire, passed through various parts of ody, indicated the temperature of the tissues in contact with the t of contact of the two metals. Passing this 1½ inch into the of the leg, the temperature was found to be 98° F., while at a h of ⅓ inch it was only 94°, showing the cooling from the sur- inwards. The superficial fascia over the biceps was nearly 3° r than the muscle itself; on compressing the brachial artery, so intercept the flow of blood, the temperature *immediately* fell al 10ths of a degree. So after the ligature of the main artery neurism, the temperature is well known to fall, and to require economized with increased clothing. Professor Fük obtained ollowing results in twelve experiments upon living dogs. No ence in the temperature was observed between the right and ventricle of the heart. The highest degree of warmth was ys met with in the vagina and rectum (101.75 to 105.79).

exercise is attended with quickened circulation, more active ration, a more abundant interchange of oxygen and carbonic so it occasions an augmentation of animal temperature. The tions are more copious—there is a more energetic nutrition— uantity of food required is greater, and we all know how much keen our appetites are, and how much more food we consume

when engaged in employments requiring active exercise, than in sedentary occupations. MM. Becquerel and Breschet have observed, that the muscles during their contraction become hotter by 2° or 3°, a fact which one of us can attest from an experiment on the biceps in his own person, made by these gentlemen themselves.

Sleep, as it is attended with diminished frequency of respiration and pulse, and a smaller evolution of carbonic acid, is also marked by a slight fall of temperature, viz., of from 1° to 3° F.

Age has been shown by Dr. Edwards to have much influence on temperature. Old persons, and very young ones, are alike unable to preserve their proper warmth without external aid, and have not the same power as adults of generating heat. For example, he found that young carnivorous and rodent animals, when placed in an atmosphere of 50° F. apart from the body of the mother, quickly became cold, though when lying near her they continued within 2° or 3° of her temperature. So, young sparrows one week old were at 97° F. in the nest, but when removed from the nest, fell in one hour to 66° F., when the external air was at 62° F.; and he showed that this result was not to be attributed to their unfledged state.

Young animals, therefore, require the aid of external warmth, or at least of every means of retaining their own warmth. The nests of birds not only serve to retain the warmth of the parent during incubation, but also that of the young brood during their tender age. The human infant stands no less in need of extraneous warmth —and it may be safely affirmed, that much of the immense mortality of our infant population is owing to the want of artificial heat.

We must refer to what has been already said in the chapter on food (Chapter XXII.), for observations on the relation of the kind of food to the animal temperature.

Influence of Climate and Seasons.—The best account we possess of the effect of climate results from 4000 experiments made on board the Bonite, a French vessel, during her passage between Cape Horn and the tropics. The mean temperature of 10 men at Cape Horn, with the thermometer at 32° F., was hardly two degrees lower than at Calcutta, where the thermometer stood at 104° F. The temperature of the body was found to rise and fall perceptibly, but slightly —to fall slowly in passing from a warm to a cold climate, and to rise more rapidly in re-entering the torrid zone.

The rate at which an animal loses its heat will depend both on the coldness of the surrounding air, and on the rapidity of evaporation. In temperate climates these causes differ inversely with the season. In winter there is much loss by radiation, little by evaporation; in summer the reverse. But Dr. Edwards has well shown that these compensations are not the only cause of the uniformity of temperature so wonderfully maintained, but that there is also in animals a difference in the rate at which heat is produced, according to the season, "the calorific faculty is more active in winter than in summer." "In winter there is a more active production with greater loss, in summer a less production with smaller loss." To test this, Dr. Edwards contrived a box surrounded with ice, having the same external tem-

rature, and the same humidity of atmosphere in winter and sumr, so that the loss by radiation and evaporation should be the ne in both cases. Into this apparatus, in February, he placed 5 arrows that had been living in a warm room, and found that after interval of 3 hours they maintained their previous heat within 1°

Again, in July, he did the same with 4 others, and these after hours were found to have lost 10° F. We may here recall the t, that the quantity of carbonic acid exhaled is greater when the ternal temperature is low. Mice and guinea-pigs evolve twice as ich carbonic acid at 32° as at 60° F., and birds more than double. so more food, and of the calorifacient kind, is required in winter n in summer, and in cold climates than in warm.

The nature of the food must vary with the temperature of the mate, for at the same time that the respirations are less in number hot than in cold climates, the air is less dense, and contains in a ren volume less oxygen; hence a light and succulent diet is better apted to the requirements of the system, and comparatively little at is developed; while, in cold climates, a large quantity of highly rbonaceous food is necessary in order to furnish the requisite sup-y of heat.

In animals which are very active, and which are not subjected to cooling influence of an atmosphere many degrees lower in temrature than their own bodies, it is quite possible that a sufficient iount of heat may be generated in the combination of the elements their tissues without the necessity of fatty or starchy food forma part of their highly nitrogenous diet. In cold climates, hower, a large quantity of readily combustible food is necessary in ler to furnish the requisite amount of heat.

Loss of Heat by Evaporation.—The animal body is continually bject to evaporation of its fluid parts, just as any other moist subince, and the amount of evaporation, and the consequent loss of at, will depend on the same causes as in the case of inorganic bstances. The moisture, or dryness, of the surrounding air, and state of motion or rest, will mainly influence the result. All the ects of excessive temperature on the body are much more apparent th a moist than a dry atmosphere; because in the case of a dry nosphere a greater amount of evaporation takes place, and hence a eater quantity of heat is removed from the system.

In England it would be impossible to sustain a vapour bath at a nperature of 110° or 120° for more than 10 minutes, whereas the dy may be without danger exposed for the same time to a dry nperature twice as high or more. In some well-known experiments r Charles Blagden remained immersed for 8 minutes in dry air ated to the extraordinary pitch of 240° or 260° F. An oppres-e day in summer is one where the air is moist at the same time at it is hot and stagnant.

Again, the refrigeration, arising from simple contact of cold air, much increased by motion of the air, *i. e.*, by a rapid renewal of sh cold particles; and all the more if the moving air be dry. A ld dry wind is one of the most powerful refrigerators, but we could

hardly realize the full extent to which this is true, without an example. Mr. Fisher, the surgeon to the expedition to the Polar Seas, under Sir Edward Parry, has related its extraordinary effects. The hardy sailors found that they could better bear a cold which would freeze mercury (viz., 40° below zero, F.) when the air was perfectly calm, than a temperature of 10° F. *i. e.*, 50° higher) when the wind was up.

The rate of cooling, and the amount of heat parted with in this manner depends upon the difference in temperature between the body and that of the surrounding medium. The loss of heat must of course be much greater in the Polar regions, where the temperature is 100° or more below that of the body, than in hot climates where the temperature of the air approximates to that of the body. Yet the temperature of the body is the same in each case. The cooling effects of cold climates are compensated for by the increased quantity of highly carbonaceous food taken, and the increased activity of the respiratory functions. A much larger quantity of carbonic acid is evolved, and a much greater amount of heat liberated, than in warm climates, where the food must be smaller in quantity, and should contain less carbon and hydrogen.

Warm clothing, by protecting the body from the influence of cold air, and so peventing the loss of a certain amount of heat, may be said, as Liebig has remarked, to be equivalent in cold countries to a certain amount of food. The appetite is increased in cold weather, and if in winter we clothe lightly we shall eat more than if warmly clad. We may often remark, that lean spare men, who take a great deal of exercise, consume many times the quantity of food which satisfies a moderately plump individual. The former has usually a larger respiratory capacity, and is less protected from the cooling influence of the external air.

Influence of Food.—If an insufficient quantity of food be taken, the temperature of the body falls, and the carbon and hydrogen, entering into the composition of the tissues themselves, combine with the oxygen, and thus a certain amount of heat is furnished. Deficiency of food is borne much more readily in a high temperature than in a low one. Cold very much expedites death from starvation. The highly important and interesting experiments of Chossat* upon animals have shown that in starvation the fatty matters, which are most readily convertible into carbonic acid, are first removed, soon afterwards the substance of the muscles is acted upon, in order to furnish an amount of heat, without the development of which life would at once cease; next the nervous system gives way to this oxidizing power—life ceases, and every portion of the organic material, with the exception of the mineral matters combined with it, is brought under the destructive influence of the oxygen. M. Chossat found that, taking 40 per cent. as the mean, fat lost 93.3, blood 75, heart 44.8, muscles 42.3, skin 33.3, bones 16.7, and the nervous system only 1.9 per cent. of their weight in fatal starvation.

* Recherches expérimentales sur l'Inanition.

[T]he time required to produce death from starvation varies accord[ing] to different circumstances. If the body be very fat, life will be [sup]ported for a longer period than if only a small quantity of fatty [ma]terial be present. A fat pig, which was confined by a slip of [ear]th, lived 160 days without food, and during this period he lost [mo]re than 120 lbs. (Martell, *Trans. Linn. Soc.*, vol. xi. p. 411, quoted [in] Liebig's letters). While death from starvation would be retarded [by] warmth, little or no exercise, and a moderate supply of water, it [wou]ld be much accelerated by the converse of these circumstances.

[I]*nfluence of Disease.*—In acute diseases accompanied with fever, [suc]h as pneumonia, pleurisy, acute rheumatism, and in scarlatina, [typ]hoid fever, etc., the temperature often rises several degrees above [the] normal standard, not unfrequently reaching 105° or 106° F. Dr. [Ed]wards observed the temperature as high as 110¾ in a case of teta[nus]. This high temperature sometimes decreases rapidly, and some[tim]es very gradually, the diminution being frequently accompanied [by] free perspiration and copious excretion of urine, rich in urea and [ur]ates. The frequency of the pulse also diminishes at the same [tim]e. This increased development of heat, during the exacerbation [of t]he fever, is associated with the increased amount of disintegration [of] tissues taking place at that time; while the remission is ac[com]panied by the elimination of the resulting compounds, free per[spi]ration, diminished frequency of pulse, and corresponding decrease [of t]emperature.*

[I]n those diseases, on the other hand, where the activity of the [che]mical processes going on in the body is impaired, the temperature [fall]s many degrees below the normal standard. In cholera, where [the] dark blood and imperfect respiration mark the introduction of an [insuf]ficient supply of oxygen, and the suspension of secretion and [the] absence of symptoms characteristic of the accumulation of ex[cre]tory products in the organism, show that the chemical changes [acc]ompanying the disintegration of the tissues are only taking place [in a] slight degree, or are altogether suspended, the temperature often [fall]s to 70°, or even much lower. It is curious that, in many of [the]se conditions, the temperature should rise very rapidly imme[dia]tely after death. The most striking examples of this have been [pla]ced on record by Dr. B. Dowler, of New Orleans, and occurred [in c]ases of yellow fever, etc. In one instance, just before death, the [tem]perature was 104°; and fifteen minutes after death, it had risen [to] 118° in an incision in the thigh. The temperature still remained [ver]y high for several hours after death.

[H]*ibernation.*—The phenomena of hibernation are dependent upon [the] conditions we have just alluded to. Previous to becoming torpid, [the] animal accumulates a quantity of fat, which is, as it were, laid [up] as in a storehouse, to be consumed slowly, while the period of [ann]ual sleep lasts. At this time, the activity of the vital functions [is m]uch reduced, the animal lies perfectly still, the frequency of the

* See a review, by Dr. H. Weber, in the *Medico-Chir. Review*, Jan. 1858, on Crises [and] Critical Days, by Dr. L. Traube. Berlin, 1852.

heart's action and of the respirations diminishes; its temperature falls many degrees, and it is placed in a condition the most favourable for supporting life for a considerable period of time with a very small supply of combustible material. The moment the animal is roused, the vital processes again become active, and a supply of food soon becomes necessary. In the case of the marmot, in which animal the hibernation is complete, the pulse falls to about 15 beats in a minute, and the respirations to about 14 in an hour, while in the waking state these are respectively 150 and 500. The temperature of the body, during the hibernating period, may fall as low as 35°. If, however, the animal be exposed to warmth, the frequency of the pulse and respiration increases, a much larger quantity of oxygen is consumed, and a corresponding proportion of carbonic acid exhaled. The temperature of the body suddenly rises, and the animal soon dies, unless supplied with food.

Theory of Animal Heat.—It has been shown, that in certain parts of *plants*, and in cold as well as warm-blooded *animals*, heat is developed coincidently with the consumption of oxygen, the combustion of carbon, and the formation of carbonic acid. The heat produced, and the chemical product of combustion, have been observed to bear a certain general correspondence one with the other.

To understand the real nature of the development of heat in organized bodies, it is necessary to remember, that the heat disengaged during the oxidation of carbon or of a metal (*i. e.* during the combustion of these bodies) is directly proportioned to the amount and not to the intensity of the chemical action. In the words of a distinguished chemist, "The rod of iron that is burnt in oxygen gas, produces a heat which no one will deny; but the iron which rusts slowly in the air, disengages just as much heat, although its temperature never rises sensibly above that of the surrounding atmosphere. Phosphorus alight burns brilliantly, and produces abundance of heat; phophorus in the cold, still burns, but with little lustre, and the heat which it evolves was for a long time denied."*

It has been already stated (p. 515–16) that a large portion of the food being destitute of nitrogen, is not the best adapted to form part of the tissues of the body into the composition of which that element enters. This *calorifacient* food (consisting of various quantities of carbon in combination with oxygen and hydrogen, in the proportion in which these last form water, as starch, sugar, cellulose, or gum, or of carbon and hydrogen in combination with a less proportion of oxygen in fatty matters) seems to be devoted in the main to the production of heat by the combination of its carbon and hydrogen with the oxygen furnished by respiration. It is a question through what changes it passes ere thus consumed; but of its eventual destination to the production of heat there would appear to be no doubt.

As was shown in the chapter on Respiration, more oxygen is taken into the blood by the lungs than is required to form the carbonic acid exhaled. This superfluous oxygen disappears, the greater

* Dumas, "Balance of Organic Nature," p. 37.

part appearing to enter into combination with hydrogen, while a small quantity goes to oxidize the sulphur and phosphorus. The air breathed is likewise found to have lost bulk. Now, gaseous carbonic acid contains its own bulk of oxygen—but oxygen uniting with hydrogen to form water is condensed. Such a condensation of the oxygen would accord with the observed diminution of bulk in air by being respired. It has been remarked that herbivorous animals return to the air, as carbonic acid, only nine out of ten of the volumes of oxygen absorbed in respiration, and that carnivorous animals return in the same form, only five or six out of ten volumes. The carnivora, then, absorb nearly twice as much oxygen as they employ for oxidizing carbon, and a very large proportion of the remainder, no doubt, combines with hydrogen to form water.

To explain the prompt oxidation of the carbon and hydrogen within the body, Liebig has pointed out that the oxygen is presented to them not in a gaseous but in a liquid or solid form—that in the innumerable channels of the circulation, these several elements are not merely brought together in a very subdivided state, but everywhere in close proximity to membranous surfaces, mechanically adapted to favour the occurrence of chemical union. Moreover, that the carbon and hydrogen are not offered to the oxygen in their pure and simple state, but in combinations already existing and ready to be dissolved. He also insists, with great force, on the analogy of these actions to those promoted by the presence of a body already undergoing oxidation. For example, "when weak brandy is allowed to trickle over shavings in a close vessel, through which a feeble current of air at from 93° to 97° F. circulates, the alcohol in the brandy remains unchanged; in spite of the greatly increased surface, no oxidation, no formation of acetic acid takes place. But if to the brandy there be added one hundred thousandth part of vinegar, beer, or wine, in the state of acetification, that is, of oxidation, the alcohol disappears with great rapidity, and is converted, by the absorption of oxygen, into an equivalent quantity of acetic acid. In the vessel, the surface of the shavings themselves very soon passes into the state of oxidation, and from this period forth, the brandy is acetified without the addition of a ferment; the wood, being in the state of decay, *eremacausis*, or slow combustion, plays the part of a ferment. These vinegar-producing vats give an idea, if only a rough one, of the process of oxidation going on in the animal body. As in the body, so also in these vessels, a temperature higher than that of the surrounding media is kept up, without the aid of external heat."*

These actions of *contact* or *catalysis* may well be supposed to play a large and most important part, not merely in the production of animal heat, but also in all the chemical changes which are ever going on in the body, from the first reception of food to the final expulsion of its elements in other forms of combination. Great

* "Animal Chemistry," p. 34, 3d edition, Part I.

obscurity, however, still hangs over the series of transformations which the food undergoes in its passage through the body.

It has been seen that both arterial and venous blood contain oxygen and carbonic acid gas in a state of solution; but into what form of combination the oxygen first enters, or from what immediate source the carbonic acid is derived, is as yet matter of conjecture only. It may be regarded as most probable that the chemical changes which issue in the formation of carbonic acid and water, and the disengagement of heat, are effected in the tissues themselves, or in the systemic capillaries, in the immediate vicinity of the tissues.

Influence of the Nervous System.—Much difference of opinion has existed as to the share taken by the nervous system in the production and maintenance of animal temperature, some distinguished men having argued that this system is in some way the source of heat, while others have limited its operation to the exercise of a controlling and regulating influence over this important function. The latter conclusion is that to which a just estimate of the numerous facts advanced on both sides would appear to lead. The experiments of Dulong, repeated and modified by Despretz, seemed, indeed, for some time to indicate that a portion of the heat developed in the body could not be referred to the consumption of the oxygen inhaled, and that, therefore, some other source for it must be sought. They compared the heat given to a calorimeter by an animal placed within it, with that produced by the combustion out of the body of as much carbon and hydrogen as the animal gave off in the same time, in the form of carbonic acid and water, and found that more heat was given off by the animal than the chemical products of its respiration would account for, to the extent of from one-fifth to one-tenth. It has since been shown, however, that, on the one hand, allowance was not made for an actual cooling down of the animal below its normal temperature by exposure to the refrigerating influence of the calorimeter, so that the heat indicated had not all been produced within the period of the experiment; and, on the other, that the heat generated by the corresponding chemical actions out of the body had been under-estimated. Dulong himself furnished a more correct estimate of the heat developed by the combustion of hydrogen; and his results have been confirmed by Fabre and Silberman. Hence, while it would be premature to attach too much value to such experiments, considering our ignorance of the exact series of chemical changes indicated by the resultant carbonic acid and water, they certainly are not, as they once seemed to be, opposed to the chemical theory of animal heat.

It may be regarded as certain that the nervous system exerts a considerable influence upon the development of heat in the body. The experiments of Sir Benjamin Brodie, and subsequently those of Le Gallois and Chossat, have established the fact that lesions of the nervous centres are accompanied with a diminution of temperature, and of the power of forming heat. Again, the temperature of paralysed limbs is almost always less than that of sound limbs, and often so to a very marked degree. In some instances, however, twin lesions of

the nervous system are followed by an opposite effect. Much light has been thrown upon the influence of the nervous system upon the development of heat, by the recent highly interesting and important researches of M. Bernard.

Bernard has lately established the very interesting fact, that section of the sympathetic nerve is followed by a considerable elevation of temperature in that side of the head or face corresponding to the divided trunk. This increase of temperature occurs immediately; and persists after all increased vascularity and turgescence have disappeared, and after the wound in the neck has quite healed. The same observer found that sections of nerves of motion and sensation produce respectively, besides paralysis, a diminution of temperature, while, if a mixed nerve containing fibres of the sympathetic, as the facial, is divided, an exaltation of temperature takes place, arising, doubtless, from the division of the sympathetic fibres. The increase of temperature seems to be a special result of the division of the sympathetic.

Now, if the upper extremity of the sympathetic, which has been divided in the neck of an animal, be subjected to an interrupted galvanic current, the exalted temperature which follows its division is no longer manifested, and the parts supplied by it actually fall below the normal standard, and they rise again when the current is stopped. When an animal, in which the sympathetic had been divided, was placed under the influence of chloroform, the temperature which had risen several degrees in consequence of the division of the nerve, fell, while it again rose when the animal had recovered from the effects of the chloroform.

Bernard has shown that the increased temperature following division of the sympathetic, or removal of the superior cervical ganglion, cannot be attributed solely to the increased quantity of blood, which is allowed to enter the vessels in consequence of paralysis of their contractile coats; for it occurs when the blood is allowed to stagnate in the vessels by tying them. At the same time, it is necessary that the vessels should contain blood. The enlargement of the vessels and the increased flow of blood to the parts are to be looked upon as the result of the altered nutritive changes which take place in consequence of the division of the sympathetic, rather than as the cause of the rise of temperature. Whatever may be the exact order and nature of the changes which ensue, they may be looked upon as a more active manifestation of the ordinary phenomena of animal heat.

This increase of temperature, which is found generally to accompany the abstraction of nervous influence, has been accounted for by the supposition that the tissues were more readily acted upon by the oxygen of the air when deprived of the protective agency of the nervous system; but although this increased action of the oxygen, or more rapid combustion, may perhaps have considerable weight in the production of these phenomena, it must, by no means, be regarded as the sole cause, nor can the chemical theory of animal heat, as it at present stands, be considered as giving an explanation of the

whole of the facts observed in connection with this highly interesting but abstruse subject.

Upon the subject of Animal Heat, the following works may be consulted: Dr. Crawford's "Experiments and Observations on Animal Heat," 1788; Dr. J. Davy's Memoirs in the Philosophical Transactions, 1814; "Recherches Expérimentales sur l'Inanition," M. Chossat, Paris, 1843; Liebig's Animal Chemistry, 3d edition; Sir Benjamin Brodie's Physiological Researches, and also papers in the Phil. Trans., 1811-12; the article Animal Heat, by Dr. Edwards, in the Cyclopædia of Anatomy and Physiology, vol. ii.; Lehmann's Physiological Chemistry; Mr. Newport on the Temperature of Insects, in the Phil. Trans., 1837; Mém. "Sur la Chaleur Animale," par MM. Becquerel and Breschet, in Ann. des Sciences Nat., Seconde Serie, tom. iii. iv. et ix. M. Bernard, "Recherches Expérimentales sur la Grand Sympathique," Paris, 1854.

CHAPTER XXXI.

VOICE.—HOW PRODUCED.—ITS EXISTENCE IN THE ANIMAL KINGDOM.—THE HUMAN LARYNX.—ITS CARTILAGES.—THEIR ARTICULATIONS AND LIGAMENTS.—CHORDÆ VOCALES.—MUCOUS MEMBRANE.—MUSCLES, EXTRINSIC AND INTRINSIC.—ACTION OF THE LARYNGEAL MUSCLES.—NERVES.—ACTION OF THE LARYNX.—THEORY OF VOCALIZATION.—CHEST VOICE.—FALSETTO VOICE.—SINGING.—INFLUENCE OF THE NERVES ON VOICE.—SPEECH.

THE high development of man's intellect, as compared with that of the lower animals, would be of comparatively little advantage without his peculiar endowment of speech. To this power, an essential subsidiary is that of producing vocal sounds or voice; which, however, he enjoys in common with a large number of the lower classes.

The phenomena of voice are produced by a very beautiful and simple mechanical contrivance, the larynx, which is placed at the top of the trachea, to take advantage, as an exciting force, of the air emitted from the lungs during expiration. The air thus expelled creates vibrations in certain tense and elastic membranes (*chordæ vocales*), the boundaries of a chink which is the orifice at once of entrance and of exit for the supply of air to the lungs. These vibrations generate voice.

That the larnyx is the organ of voice is proved by the following very obvious facts: first, the least alteration in the condition of the mucous membrane covering the vocal chords is invariably accompanied by a change in the tone of the voice, *e. g.* hoarseness; secondly, ulcerative disease eating through one or both of these vocal chords destroys or greatly impairs the voice; thirdly, opening the trachea below the vocal chords, so as to divert the current of air in expiration from the larynx, will destroy voice; and fourthly, section of the inferior laryngeal nerves, by which the influence of the will is brought to bear on its muscles, and so the tension of the vocal chords is regu-

lated, destroys the voice; lastly, by experiment on the dead larynx, sounds may be produced resembling those of the voice. If a current of air be made to play on the vocal chords by a bellows fixed to the tracheal end of the larynx, or by blowing air through it, distinct vocal sounds are excited which can be varied by altering the tension of the vocal chords.

There is no instance of true voice among the lower orders of creation except in those animals that have a larynx connected with the respiratory apparatus, as in man. In other words, all animals that have no larynx are voiceless. The hum of insects is a phenomenon essentially different from voice, and is caused by the rapid vibration of an apparatus connected with their wings. All the other invertebrated classes are incapable of producing sounds. Fishes, likewise, are voiceless. The Batrachian reptiles possess a larynx and can produce vocal sounds. The hissing of serpents is, likewise, laryngeal. But the Chelonian reptiles have no voice. In birds there are two organs placed, the one in front of the other, to which the name of larynx has been given by anatomists; of these, the lower, or that nearest the lungs, is the true vocal apparatus; the upper is merely a resonating or reciprocating cavity destined to enhance the intensity of the sounds generated in the lower. Cuvier showed that an opening between the two organs did not destroy the power of producing sounds, so long as the inferior larynx was uninjured.

Fig. 210.

Cartilages of larynx and epiglottis, and upper rings of trachea *in situ* seen from behind. From a preparation in the Anatomical Museum, King's College, by Mr. Cane.

a. Arytenoid cartilages. *b.* Superior cornu. *c.* Inferior cornu. *d.* Posterior surface of cricoid. *e.* Foramen for superior laryngeal nerve. *f.* Perforations of epiglottis. *i.* Upper margin of thyroid. *t.* Trachea. *h.* Right inferior tubercle.

The *human larynx* is a kind of box, composed of pieces which may be moved on each other, and incloses the membranous bands in which the vocal vibrations are produced. These pieces, when articulated together, constitute the skeleton of the larynx. They are composed of cartilage, and form a very curious mechanism. There are five distinct pieces (two of which are symmetrical) essential to this mechanism, and there are four smaller, accessory cartilages. The first are the cricoid and the thyroid cartilages, the epiglottis, and the arytenoid cartilages, which are symmetrical. To these may be added the cuneiform cartilages and the cornicula, which are merely sesamoid

bodies destined to keep the folds of mucous membrane in proper position.

The *cricoid* catilage is a ring, whose lower margin is parallel to, and united by fibrous membrane with the first ring of the trachea. Its upper margin slopes from behind forwards, and from above downwards, so that the posterior surface of the cartilage is considerably deeper than the anterior, and affords two large concave surfaces for the attachment of the posterior crico-arytenoid muscles. Its upper border is connected in front with the lower margin of the alæ of the thyroid cartilage by an expansion of yellow fibrous tissue, which is particularly thick in front, called the crico-thyroid ligament, and which fills up the space called by surgical anatomists the crico-thyroid space. This space and ligament, bounded on each side by the crico-thyroid muscle, are penetrated by the trocar in the operation of laryngotomy. The posterior half of the upper border of the cricoid cartilage exhibits on each side an oval convex articular surface on which plays one of the arytenoid cartilages.

The *thyroid* cartilage consists of two square plates of cartilage (*alæ*) united at an acute angle in front; each of these is prolonged at the upper and lower corners behind, into a long superior process (*superior cornu*) and a very short inferior process (*inferior cornu*). By the superior process, and along the whole superior border of its alæ, the thyroid cartilage is united to the os hyoides by the thyro-hyoid ligament. Each inferior process rests upon the outer surface

Fig. 211.

A

A. Thyroid cartilage. *a.* The notch. *b.* Superior cornu. *c.* Inferior cornu. *d.* Slight prominence at median lines of inferior margin for the attachment of crico-thyroid ligament. *g, h.* Superior and inferior tubercles. *e.* Ala. *f.* Pomum Adami.

B. Cricoid cartilage seen from the side. *a.* Posterior superior margin. *b.* Articulating surfaces of arytenoid cartilages. *f.* Superior descending margin. *h.* The right surface articulating with inferior cornu of thyroid.

C. The right arytenoid cartilage. *a.* Base; position of the crico-arytenoid articulating groove. *c.* Lateral prominence at base, which gives attachment to the crico-arytenoideus lateralis and posticus. *d, b.* Convex triangular surfaces for the attachment of the superior thyro-arytenoid ligament. *f.* Corniculum laryngis; between *f* and *e*, the posterior aspect of the arytenoid cartilage and concave surfaces giving attachment to the oblique and transverse arytenoid muscles. *g.* Vertical portion of cuneiform cartilage.

of the cricoid cartilage, and plays upon a small circular plane articular facet situated thereon.

By the angular union of the two alæ of the thyroid cartilage in front, a projection is formed beneath the integuments which is most prominent in the male, and is commonly known as the *pomum Adami.* Into the hollow angle behind, the vocal chords are inserted, and also the stalk and ligament of the epiglottis. The broad outer surfaces of the alæ give attachment to muscles along an oblique line, which is sufficiently conspicuous between the middle and lower third of each. The thyro-hyoid and sterno-thyroid muscles are thus attached. To the inner surface of each ala are inserted the thyro-arytenoid and the crico-thyroid muscles.

By the gliding of the inferior horns of the thyroid upon the articular facet on the outer surface of the cricoid cartilage, a movement of the one cartilage may take place on the other, round an axis passing transversely through the cricoid. By this movement, the crico-thyroid space may be enlarged or diminished according as the cartilages separate from or approximate each other in front.

The *arytenoid* cartilages are two pyramidal bodies articulated by their bases with the oval articular surfaces, already described on the upper margin of the cricoid cartilage. Each presents a concave posterior surface in which is implanted the arytenoid muscle which passes from one cartilage to the other; an inner smooth surface covered by mucous membrane, and an outer surface which gives attachment to the crico-arytenoid muscles. From the anterior angles of the bases of the arytenoid cartilages proceed the vocal chords to be inserted into the angle of the thyroid. The mobility of the articulation of the arytenoids with the cricoid, and their connection with the vocal ligaments give them great importance in the mechanism of the larynx.

The *cornicula* and the *cuneiform* cartilages are placed beneath the mucous membrane—the former at the apex, the latter parallel to the anterior border of the arytenoid cartilages.

The *Epiglottis* is a remarkable valve-like cartilage, in shape like the spout of a ewer. It seems to issue from the angle between the alæ of the thyroid cartilage, to which it is attached by a stalk-like ligament. It projects above the root of the tongue, and lies between that organ and the aperture of the larynx, like a valve, which is pressed over the glottis when the tongue is retracted. Its upper border is convex, and its posterior surface is concave, transversely convex in its length. It is a smooth and very flexible cartilage, covered by a mucous membrane, but penetrated by holes and depressions in which are lodged the numerous mucous glands of the membrane that covers it.

Such is the skeleton of the larynx; it hangs from the hyoid bone, suspended by the thyro-hyoid ligament and muscles, and, through the hyoid apparatus and some muscles, it is brought into connection with the lower jaw and the base of the cranium.

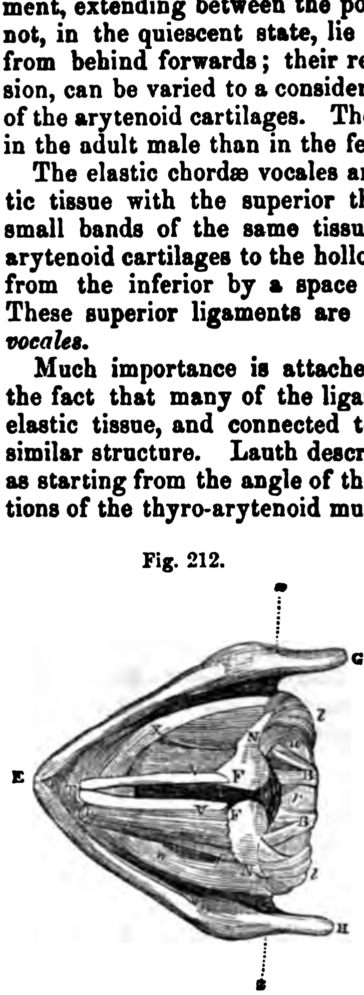
Vocal Chords, or Superior Thyro-Arytenoid Ligaments.—The various cartilages of the larynx are connected to each other by liga-

ments. Of these, the most important and interesting, as being the essential part of the mechanism for producing vocal sounds, are the bands of fibrous tissue which extend from the anterior angle of the base of the arytenoid cartilages to the angle between the wings of the thyroid. These are the thyro-arytenoid ligaments, or, in physiological language, the *vocal chords*. They are bands of elastic ligament, extending between the points named (*t*, *v*, Fig. 212). They do not, in the quiescent state, lie parallel to each other, but converge from behind forwards; their relative position, as well as their tension, can be varied to a considerable degree by reason of the mobility of the arytenoid cartilages. The length of the vocal chords is greater in the adult male than in the female, being as 3 : 2.

The elastic chordæ vocales are connected by an expansion of elastic tissue with the superior thyro-arytenoid ligaments, which are small bands of the same tissue, extending from the apices of the arytenoid cartilages to the hollow angle of the thyroid, and separated from the inferior by a space called the ventricle of the larynx. These superior ligaments are likewise known as the *false chordæ vocales*.

Much importance is attached by Lauth, Müller, and others, to the fact that many of the ligaments of the larynx are composed of elastic tissue, and connected together by a fibrous expansion of a similar structure. Lauth describes the elastic tissue of the larynx as starting from the angle of the thyroid cartilage between the insertions of the thyro-arytenoid muscles, whence the fibres radiate downwards, obliquely backwards, and even somewhat upwards, forming a continuous membrane, which passes to the cricoid and arytenoid cartilages, lines the ventricles of the larynx, and is connected with the crico-thyroid ligaments and the vocal chords, both true and false. The thyro-hyoid ligament is likewise elastic; and also the fibrous bands which connect the epiglottis to the thyroid cartilage, and hyoid bone, and the tongue. "If," says Müller, "we add to these parts the elastic longitudinal fibres in the membranous part of the trachea and bronchi, we shall have an idea of the great extent of the tissues susceptible of consensual vibration and resonance in the parts surrounding the organ of voice."*

Fig. 212.



View of the larynx from above, after Willis. B. Ligaments uniting arytenoid and cricoid cartilages. *x* and *z*. Direction of axis on which the thyroid cartilage turns. E. Thyroid cartilage. *k*. Left thyro-arytenoid muscle; right removed. *r*, *u*, X, W. Cricoid cartilage. N, X. Right crico-arytenoid muscle. N. Arytenoid cartilages. *l*. Crico-arytenoidic postici muscles. *r*. Posterior part of cricoid cartilage. T, V. Vocal ligaments.

The mucous membrane of the larynx is part of the great respira-

* Müller's Physiology, by Baly, vol. ii. p. 1005.

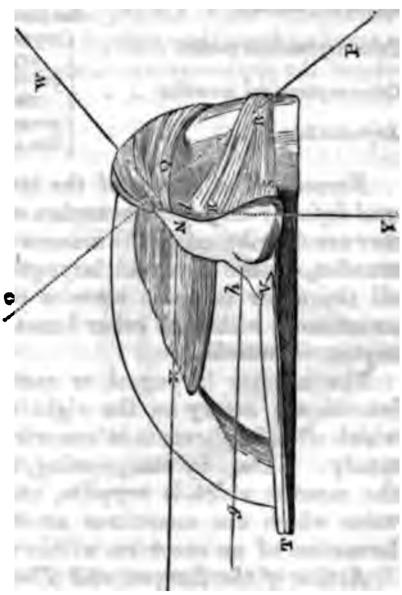
tory tract, described at page 523, and possesses the same anatomical characters at many points, being covered by ciliated epithelium. It is involuted to a considerable extent, forming numerous glands, which cover the epiglottis, and are scattered over the interior of the larynx.

We have seen that the cricoid cartilage may move freely on the thyroid, or *vice versa;* and the arytenoids may be moved in various directions on the upper border of the cricoid. Moreover, suspended as it is, loosely in front of the pharynx and œsophagus, the whole apparatus of the larynx may be moved freely up and down in the neck, approximating, or receding from the lower jaw. For these various movements the larynx is provided with two sets of muscles—the *extrinsic*, by which the whole organ is moved, and the *intrinsic*, destined to regulate the movements of the various segments.

The *extrinsic* muscles are those which connect the larynx to the sternum below and the hyoid bone above; the sterno-thyroid, the thyro-hyoid, and, indirectly, the sterno-hyoid, omo-hyoid and stylo-hyoid, and stylo-pharyngeal muscles.

The *intrinsic* muscles are the crico-thyroidei, the arytenoidei, the crico-arytenoidei-postici and laterales, and the thyro-arytenoidei. We must refer to works on descriptive anatomy for the details of the connections of these muscles; it must suffice, here, to state that their names denote very accurately their attachments to the segments of the larynx upon which they can exert their force.

Fig. 213.



Magnified view of internal parts of larynx of right side, after Willis, showing actions of laryngeal muscles.

O, P. Axis of articulation of arytenoid cartilage. T. Direction of force of thyro-arytenoid muscle. X. Direction of force of crico-arytenoideus lateralis. W. Of crico-arytenoideus posticus. Y. Of arytenoideus transversus.

B. Crico-arytenoid ligaments. X. Crico-arytenoideus lateralis. Q. Crico-arytenoideus posticus. A. Vocal ligament.

Action of Laryngeal Muscles.—The arytenoid cartilages are attached by ligaments to the posterior surface of the cricoid, which permit a considerable extent of rotation upon an articulating surface formed on the summit of the latter; by this arrangement the chordæ vocales may be stretched or relaxed, and the aperture of the glottis increased or diminished, according to the direction of the force which acts upon the arytenoid cartilages. The posterior crico-arytenoid muscles render the vocal chords more tense, but at the same time cause them to diverge from each other, and so the width of the aperture of the glottis is enlarged. On the other hand, the thyro-arytenoid muscles, by drawing the arytenoid cartilages towards the thy-

roid, relax the vocal ligaments, while the crico-arytenoidei laterales, by causing the arytenoid cartilages to rotate inwards upon their axes, approximate the vocal chords and diminish the aperture of the glottis. The arytenoid muscle draws the two cartilages towards each other, and so tends to diminish the aperture of the glottis, especially at its posterior part.

These different movements are further accelerated, or increased in extent, by the action of certain other intrinsic and extrinsic muscles of the larynx.

Thus the arytenoid cartilages being fixed by the contraction of the arytenoid and posterior crico-arytenoid muscles, the vocal chords will be stretched by the descent of the thyroid cartilage over the cricoid, a movement performed by the crico-thyroid and sterno-thyroid muscles. The thyro-hyoid muscle, by drawing the thyroid cartilage upwards towards the hyoid bone, will assist the action of the thyro-arytenoids, and relax the vocal chords.

By the action of these various muscles, the tension of the vocal chords may be increased or diminished, and the size of the opening of the glottis regulated at will.

Modes of altering the aperture of the Glottis and the tension of the Vocal Chords.

Crico-thyroidei	stretch the vocal chords		govern pitch of notes.
Thyro-arytenoidei	relax and place the vocal chords in the position for vocalization . .		
Crico-arytenoidei postici . . .	separate the front of the arytenoid cartilages .	open glottis	govern aperture of glottis.
Crico-arytenoidei laterales . .	press together the front of the arytenoid cartilages	close glottis	
Arytenoidei	press together the back of the arytenoid cartilages		

Nerves.—The nerves of the larynx are derived from the *superior and inferior laryngeal* branches of the vagus. Those from the former are distributed to the mucous membrane, and to the crico-thyroid muscles, by the external laryngeal branch, those from the latter to all the other intrinsic muscles of the larynx. Both these nerves anastomose with each other beneath the mucous membrane, near the arytenoid muscles.

The inferior laryngeal or recurrent nerve has relations to the innominata artery on the right side, and to the aorta on the left, which often implicate it in aneurismal tumors, especially of the latter artery. These, by compressing, weaken and paralyze the nerve and the muscles which it supplies, and give rise to those alterations of voice which are sometimes among the earliest indications of the formation of an aneurism within the chest.

Action of the Larynx and Theory of Vocalization.—In the little apparatus of vocal chords attached to movable cartilages and bounded by a free space above the laryngeal ventricles, and by a free space below the tube of the trachea, in which they vibrate, are found the chief conditions necessary for the production of the vocal sounds over an extensive though variable range of pitch.

Although all physiologists are agreed that this apparatus is the seat of the production of vocal sounds, there has, nevertheless, been

such difference of opinion as to whether the larynx should be regarded as a stringed instrument, in which the sound depends upon the vibrations produced by the movement of the stretched strings, as a wind instrument, in which sounds result from the vibration of the column of air within them, or as a reed instrument which develops sound by the vibration of one or more highly vibratile tongues acted on by a current of air passing over them.

By the mechanism we have described, the vocal chords are placed in a position favourable for the production of sounds by their vibration, and the pitch of the sounds so produced modified.

Professor Willis showed, that in an ordinary respiration the aperture of the glottis assumed a V form; and its lips are inclined from each other; the apex of the V is situated towards the thyroid cartilage. When sound is to be produced, the lips of the glottis are made to approximate each other, and their inner edges become parallel. If now a current of air be forced through the chink, a sound is produced, the pitch of which depends entirely upon the tension of the vocal chords. De Kempelin says, that in the production of sounds the lips of the glottis are approximated to the one-tenth or one-twelfth of an inch. The chords in vocalization vibrate throughout their whole length; but no voice-sounds can be produced by the passage of air through the posterior portion of the chink of the glottis between the arytenoid cartilages. Even when the chords are in contact, sound is produced by the forcible transmission of air.

When the vocal chords are rendered tense, a high note is produced; when they are relaxed, a note of low pitch results. A greater number of sonorous vibrations takes place in the former case than in the latter. It has been shown, that in the case of stretched strings, the pitch of the note varies in direct proportion to the amount of tension, according to the law that the number of vibrations produced by strings of similar length varies in proportion to the square-roots of the forces which stretch them. A string stretched by a certain force will produce twice the number of vibrations, if the force be increased four times; or, if a stretched string is caused to vibrate, and so to produce a certain note, if four times the force be employed, we obtain a note which is the octave of the first, requiring for its production twice the number of vibrations. These results, however, cannot be obtained upon the larynx, so that, as Müller has proved, the production of vocal sounds in this organ cannot be compared with those produced in a stretched string.

The distinguished *physician*, M. Savart, was among the most active supporters of the explanation of the formation of voice, on the principle of wind-instruments. He likened the larynx to a bird-call, and referred the exact seat of the development of sound to the air contained in the ventricles of the larynx, which would be affected by the upward current from the trachea, just as the air in the cavity of the bird-call is by the current from the mouth. But, to pass over the argument, that it is very doubtful whether the bird-call can be referred exclusively to the class of wind-instruments, M. Savart's views are decidedly negatived by the fact that in the class of rumi-

nants the superior or false vocal ligaments are absent, and, consequently, the ventricle of the larynx.

Ferrein was the first to show, by experiment, that vibration of the vocal chords was the essential cause of voice. His experiments, published in 1741, were performed on the dead larynx. By them he was enabled to show, that the note varied according to the length and tension of the vocal chords, the same laws regulating the production of sound by these chords as by strings which are thrown into sonorous vibrations by currents of air.

The most important experiments upon the production of vocal sounds are those of Professor J. Müller, of Berlin, and of Professor Willis, of Cambridge. Müller investigated the action of membranous bands, or of tongues formed of caoutchouc, in generating sound under the influence of a current of air. The human organ of voice is imitated by a tube, capable of being varied in length; to one end of this are applied two membranous vibrating tongues, attached to the wall of the tube, but separated from each other by a chink, through which passes the current of air necessary for throwing them into sonorous vibrations. Willis employed a similar instrument.

The results of these experiments may be thus briefly stated—

1st. That elastic bands, forming the lateral boundaries of a chink through which a current of air is driven by a pair of bellows, may be thrown into vibrations so as to produce sounds which resemble those of the human voice.

2d. That for such vocalization it is necessary that these bands should have, in addition to a certain degree of tension, a particular position likewise. This, which is called by Willis the *vocalizing position*, consists in the parallelism of the margins of the bands. In the quiescent state, during breathing, the lips of the glottis are inclined from each other; but in the vocalizing position, or that necessary for the production of voice, they become parallel. In the former condition, the glottis is a triangular space, with divergent sides and apex in front; in the latter, it becomes a simple slit, or nearly so, with parallel sides. In the human larynx, the thyro-arytenoid muscles, lying on the outside of each of the vocal chords, exercise a principal influence in determining their relative position, and in adapting them for vocalization.

3d. If a tube be adapted to the membranous tongues, in such a manner that the air may play upon them through it, and may pass through another tube after it has acted upon them, an influence is exercised not only on the timbre of the sounds produced, but also upon the pitch, which varies with the length of either and of both. In the human organ of voice, the larynx and bronchi represent a tube prefixed to the membranous tongues and chordæ vocales; and the cavity in front of the inferior ligaments of the larynx, a tube placed below the tongues.*

* The reader is referred for the detail of Müller's experiments to p. 988 *et seq.*, of Dr. Baly's Translation, vol. ii., and to Müller's separate work, Ueber Compensation der phys. Kräfte am menschlich. Organ—Berlin, 1839.

The vocal sounds may be produced by blowing air from the trachea through the aperture of the glottis in a larynx removed from the dead body; and by adopting means to vary the tension and the relative position of the vocal chords, the phenomena of the voice may be very closely imitated. When air is thus blown through the glottis, the vocal chords being approximated, clear and full tones are generated. They are produced most readily and certainly when the posterior part of the glottis, situated between the arytenoid cartilages, is closed. A certain constriction of the glottis appears necessary, as, when it is too open, an indistinct noise is merely produced. The pitch of the note is determined by the tension of the vocal chords, that of both being equal; it is not influenced by changes in the width of the aperture of the glottis. By increasing the weight which stretches the vocal chords, the height of the notes is raised; on the other hand, the relaxation of the chords lowers the notes: a register of about three octaves may be formed in this way. Even after all the parts which lie over the vocal chords have been removed, these variations of sound may still be produced.

Fig. 214.

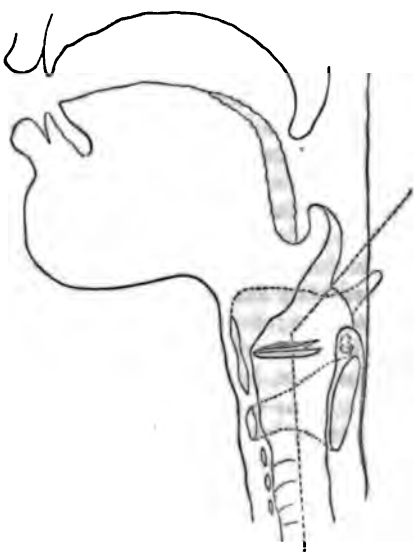


Diagram to show parts concerned in vocalization, and the character and shape of cavities above and below the vocal chords.

The action of the vocal organ in man appears to approach more nearly to that of a reed instrument than to a stringed instrument. The former is characterized by being provided with a flexible vibrating tongue, against which the air can be propelled so as to throw the tongue into vibration, and to excite a musical sound. Such is the mechanism in the organ-pipe, hautboy, bassoon, accordeon, and other instruments; the form and disposition of the tongue, and the material of which it is made, differing in each instrument.

Chest Voice.—In the larynx, as before remarked, the note may be changed, by varying the tension of the vocal chords, provided they be parallel and sufficiently close to each other. When a high note is to be produced, the head is raised and the larynx elevated, in order that the vocal chords may be rendered tense; on the other hand, if we wish to sound a very low note, the chin must be depressed upon the chest, so as to facilitate the relaxation of the vocal ligaments. At the same time, the strength of the blast of air exerts a considerable influence upon the pitch of the note. In reed instru-

ments, it has been found that the note can be rendered higher by increasing the force of the blast.

Falsetto Notes.—The sounds to which we have been referring are produced solely by the vibration of the chordæ vocales; modified no doubt by the epiglottis, soft palate, etc., and the laryngeal cavity below. These notes are all termed chest notes; but in man tones can be generated very different from those which can be imitated by experiments upon the dead larynx. These are the falsetto notes. The precise mode of their production is obscure. From the experiments of Müller and Lehfeldt, it is probable that these falsetto notes are produced by the vibration of the inner portion of the borders of the vocal ligaments solely. Magendie and Mayo accounted for them upon the view, that only half the length of the chords was thrown into vibration.

Mr. Bishop has shown, that in the transition from the chest note to the falsetto note the crico-thyroid chink opens, having been closed immediately before, during the production of the highest note of the chest voice; so that the vocal ligaments become relaxed; a change which necessarily follows must take place, if they are to produce a similar note, by vibrating only along half their length.

Singing.—In singing, a certain succession of tones is produced in definite order by altering the character of the glottis, just as by varying the conditions under which the air is thrown into vibrations in musical instruments we are enabled to alter the nature of the note.

The different varieties of the voice are arranged according to the pitch, which depends upon the length and other conditions of the vocal ligaments, and they are comprised in the following classes: *Bass*, *Tenor*, *Alto* or *Contralto*, *Soprano*; the two former belonging to the male, and the two latter to the female sex. Besides these, the *Barytone* is placed between the Bass and Tenor, and the mezzo *Soprano* between the Soprano and Contralto. The compass of the voice varies from one to three octaves. Few singers possess a greater range of voice than the latter, but some of the most celebrated have much exceeded this—Catalani's voice included three and a half octaves. The compass of each kind of voice is shown in the following table:—

SOPRANO.

CONTRALTO.

$C\,D\,E\,F\,G\,A\,B\,C^1D^1E^1F^1G^1A^1B^1C^2D^2E^2F^2G^2A^2B^2C^3D^3E^3F^3G^3A^3B^3C^4$

BASS.

TENOR.

Before puberty, the pitch of the male and female voice is nearly the same; but at this period the larynx of the male becomes larger and more prominent, and the vocal ligaments elongated, in virtue of which changes the pitch falls an octave in extent. In eunuchs this alteration does not take place, and they retain the puerile character of voice, which is, nevertheless, louder and stronger than in women.

In men the vocal chords are one-third longer than in women, and the larynx is altogether much larger.

Unlike musical instruments, the human voice is capable of producing a vast number of notes, intermediate between the successive ones; and Dodart estimates the number of these which can be appreciated by the ear at three hundred.

Influence of the Nerves on Voice.—The inferior laryngeal and the crico-thyroid branch of the superior laryngeal, from the pneumogastric, are the sole channels through which the operations of the will affect the mechanism concerned in the production of the voice-sounds, and as occurs in the case of other muscles, the movements of those muscles whose office it is to regulate the tension of the vocal chords, and govern the aperture of the glottis, are much more rapid and perfect, much more under the control of the will, and capable of executing more delicate movements in some persons than in others; and hence the wide difference between individuals as to their capacity for singing and vocalization. Something in the difference of vocalizing power is due to minute and inappreciable differences in the length of the vocal chords—size of glottis—quantity of the elastic vocal chord tissue—of the mucous membrane (slight affections of which create hoarseness).

The movements of the laryngeal muscles, as are the movements of respiration, are much influenced by mental emotions. In laughter, crying, sobbing, we have a combined excitement of respiratory and vocal actions.

In health, the emotions of grief, joy, and surprise, affect both voice and speech—the latter more frequently and intensely than the former. Diseases which involve more or less disturbance of the centre of emotions, affect both voice and speech. Hysteria, and chorea, may be referred to, the former generally affecting the production of voice, the latter of speech.

In certain affections of the brain, speech is impaired or altogether destroyed, or at most limited to a monosyllable, *Yes* or *No*. This occurs under various conditions; sometimes in consequence of a chronic disease, sometimes of a shock: a diseased state of the convolutions or hemispheres is the most frequent concomitant of this symptom, but no precise part of the brain can be assigned as a special organ of speech.

In many diseases of a spasmodic or convulsive character, the action of the muscles of the larynx is affected. In the spasmodic croup or crowing inspiration of children, the chink of the glottis is frequently so firmly closed, and for so long a time as to endanger life. The peculiar "hoop" of hooping-cough, and the curious voice-sounds so common and so varied in hysteria, show that either these nerves themselves or the precise part of the centre with which they are connected, are influenced by the morbid action. In chorea the same want of power of co-ordinating the movements is observed in the little muscles of the larynx as in those which preside over the movements of the limbs and other organs.

In some of the conditions to which we have referred, it is difficult

to say whether the motor nerve or its central origin is affected, or whether the disturbance is not excited in the centre through the influence of an afferent nerve. Anything irritating the delicate mucous membrane of the larynx creates violent spasmodic action of the muscles of the glottis, in which those of respiration frequently take part, through the medium of the *afferent* superior laryngeal nerve.

Pressure upon the inferior laryngeal excites spasmodic cough, which often forms an important symptom of aneurism, or of mediastinal tumor. Section or disease of the inferior or laryngeal nerve completely destroys the power of vocalization.

Stammering, at least in the greater number of instances, is an affection of the nervous system, not of the articulating organs. It consists in a defective control over the will, and an imperfect power of co-ordinating the muscles of speech. Stammering is much increased by any mental excitement, sudden surprise, etc., and one of the most important points to be kept in view, in the treatment of this condition, is to avoid all cause of excitement to the patient, and to prevent him from thinking about his condition as much as possible, so that he may gradually obtain that command over the movements of the muscles which is required for conversation.

Speech.—In the vocal apparatus, *notes* of very various pitch can be produced at will. The different sounds of voice have been shown to be due to variations in the size of the aperture of the glottis, and in the tension of the chordæ vocales. The vocal organ, however, is not capable of producing those articulate sounds by which we are enabled to communicate to each other our ideas; but this end is obtained by an alteration taking place in the cavity situated above the glottis, and in the position of the organs which it contains.

The most important conditions affecting speech are, first, the size of the oral aperture; secondly, the size of the buccal cavity; and thirdly, the position of the tongue.

The production of vowel sounds, which are continuous, and can be prolonged at will, depends entirely upon the size of the buccal cavity and outlet. In the sound of the *a* in *ah*, these are opened to their widest extent, while in sounding *a* in *fate*, the buccal cavity requires to be much reduced in size, by the lateral expansion and elevation of the tongue. When we sound the *e* in *me*, cavity and outlet are made still less. The *o* in *no*, results from a still further diminution of the oral aperture, while the buccal cavity is much increased; and in the *oo* in *boot*, the former is contracted to a minimum, and the latter increased to its largest size.

The sounds just enumerated are the vowel sounds of continental languages, and they can all be prolonged for a time limited only by the passage of the air through the vocal apparatus. The English *i* may be looked upon as a diphthongal sound, and, like the true diphthongs, cannot be prolonged like a continued vowel sound. The diphthongal sounds appear to be produced by causing one particular vowel sound to pass into another with a considerable degree of rapidity, thus: *ou* is formed by the transition of the *a* in *far* to the *oo* in *cool*.

n the pronunciation of consonants, the soft palate, the tongue and more especially, take part; and in order to produce many of the ads, it is necessary that the air should be forced through the pas-ss suddenly, and often with a considerable degree of force, while ers can be produced as continuous sounds, like the vowels; hence divisions into *explosive* and *continuous* consonants.

'he former class includes the b, p, d, t, g, k, the latter, the v, f, ., n, r, the sibilant consonants s and z, and the Greek θ (*theta*) *th*, ch, like *sh*, is a perfectly simple sound, and might be represented one letter. The manner in which these sounds are produced, by alteration of the position of the organs concerned in the produc- of speech, can be studied by every one in his own person; but a full description of the position of the several parts concerned producing them, the reader is referred to the works enumerated he end of the present chapter.

r information upon the subjects treated of in the present chapter, the student is red to the following works: Dissertatio de Loquela, 1700; Rev. Mr. Willis in the mbridge Philosophical Transactions," vol. iv., 1832; Lauth, "Mem. de l'Acade- Royale de Médecine," 1835; J. Müller, "Elements of Physiology," translated by Baly; Articles "Larynx" and "Voice," by Mr. Bishop, in the Cyclopædia of tomy and Physiology.

CHAPTER XXXII.

SECRETION.—SECRETIONS AND EXCRETIONS.—SECRETIONS WHICH RE EXCREMENTITIOUS.—SECRETIONS WHICH ARE NOT EXCREMEN- ITIOUS, WHICH SERVE ULTERIOR PURPOSES.—VICARIOUS SECRE- ION.—INGESTA AND EGESTA.—ANATOMY OF SECRETING ORGANS ENERALLY.—OF THE GLAND-CELL.—OF THE DUCTS OF GLANDS.

THE function of *secretion* is that by which organized bodies *sepa-* from some portion of their internal or external surfaces a ma- al which thereby becomes free or loose, and capable of removal, which is likewise commonly known as the *secretion* from such faces. It is not sufficient that this material should be separated ply from the blood; for, if this were so, all the tissues would be retions; but it must also be separated from a tissue of a special d, hence known as a secreting tissue. The blood, then, furnishes materials which are to form the secretions; but certain tissues required, without which, these materials could not become secreted ducts: and the secreting tissues are anatomically arranged so as have one surface adapted to set free, in the form of secretions, the terials derived on the opposite surface from the blood.

A secretion may be solid or fluid, living or dead, near to, or dis- t from, the constituents of the tissues in chemical constitution, able of re-entering the blood, and being further serviceable in

the economy, or requiring to be expelled from the system as useless or hurtful. Thus, a great variety of very dissimilar products are conveniently classed together as secretions, in virtue of their being separated from the body by tissues provided for that purpose.

Excretions.—Some secretions consist mainly of substances resulting from the waste of the tissues coincident with their nutrition or renewal, and which are thrown off from the blood through the secreting surfaces almost as soon as the capillaries receive them from the tissues. Such are the urine, and portions of those matters which escape in the form of fæces; and, allied to these, is the carbonic acid, which is eliminated, without the intervention of a true secreting tissue, directly from the capillaries of the lungs. If these matters were retained, they would accumulate in the blood and tissues, and prove, sooner or later, incompatible with life; and even a simple delay or retardation in the process of their removal, to whatever cause it may be attributable, must be attended with grave consequences to health. It is, therefore, impossible to over-estimate the importance of distinguishing these products from other secretions, and of acquiring the habit of considering them under one common head. They are known as the *excrementitious secretions*, or, simply as *excretions.*

The kidneys are organs through which a large portion of the blood is constantly flowing, and in which the general mass of that fluid becomes so far purified as to be freed from certain waste materials which have just been thrown into it by the muscular and other tissues. The blood which leaves the kidneys, though rendered venous by the nutrition of the glandular tissue itself, is more free than before to receive the refuse of the other parts. Hence the kidneys must be regarded as a depurating organ, subservient to the functions of other parts of the frame. To prove this, it is only necessary to extirpate the kidneys from an animal, or to see their function arrested by disease: in either case, the blood and tissues become more and more loaded by the urinary matters which continue to be formed in the body, and which should have been eliminated as soon as formed by the extirpated or diseased organs. So essential, indeed, to animal life, is this excretion of nitrogenized matters, resulting from the waste of the nitrogenous tissues, that it may be safely said to be universally present, and to have a kidney, or analogous organ, assigned to it, wherever animals exist having an arrangement of different and mutually dependent parts, on such a scale as to render the direct expulsion of the waste materials at the points where they are formed impossible.

The principal *excretions* may be thus enumerated: 1. *carbonic acid gas*, formed by the action of the oxygen upon carbon, and separated by the lungs; its accumulation in the blood is very rapidly fatal to life. 2. *Urea*, *uric acid* (in herbivorous animals *hippuric* acid), *kreatine*, and *kreatinine:* all nitrogenized principles of definite composition, resulting principally from the waste of the tissues, and eliminated by the kidneys; their retention in the blood is soon, but less rapidly, fatal. 3. Various *saline matters*, separated by the kid-

neys and skin. 4. *Lactic acid*, principally by the skin. 5. Certain portions of the *bile*, already considered (see p. 602), by the liver. To these may be added sundry constituents of the fæces, of imperfectly known composition, but supposed by Liebig to be imperfectly oxidized matter,* escaping by the mucous lining of the intestinal tract, probably by the tubes of Lieberkühn and by the solitary glands; and lastly, also, whatever substances are taken in as food and absorbed into the blood, but which fail to be assimilated, either from their being superfluous in quantity, or incapable of serving any purpose in the economy.

Secretions which are not composed of excrementitious substances, and which serve important offices in the economy.—Other secretions (and this is a large and diversified class) do not consist of waste materials, the results of the disintegration of the tissues, but are thrown off in certain situations where they are to perform a part useful or necessary to the protection or preservation of other organs, or of the whole body, or of the species. Of these, speaking generally, it may be said that they are *formed*, as well as eliminated, by the several organs which furnish them; that they retain more or less resemblance, in chemical constitution, to the food and the nutritious parts of the blood; and that, in many respects, they are allied to the living tissues of the body from which they are separated.

The highest example which can be given of these qualities is that of the male and female elements, the semen and the ova, which go to form the new being, and which are the production of organs essentially secreting. Here the secreted matter retains its organized form and its living properties, which latter are of so elevated a character, as to end in the development of an entire organism like that which has furnished the secretion.

Other examples, in which these qualities meet less decidedly, are presented by the milk, and by some of those secretions which have been already considered under the head of the digestive function, such as the saliva, the gastric juice, and the pancreatic fluid. These are poured out to mingle with the food, and variously to facilitate its entry into the blood; and there can be no doubt, that after having duly effected this object, they become in a considerable measure themselves reabsorbed with the food, so as to be further serviceable for a time in the ever-moving circle of the functions of vegetative life. There is no waste here; and we may suppose that they do not become finally expelled until they have been reduced to forms of combination in which they can no longer minister to the life of the tissues. Such secretions are conveniently classed together as *recrementitious*.

But it would be an error to suppose that all matters separated from the natural surfaces of the body fall exclusively under one of

* The fæces have lately been subjected to chemical investigation by Dr. W. Marcet, who has discovered an organic crystalline substance of an alkaline reaction, to which he gives the name of *Excretine*, an acid olive-coloured substance of a fatty nature, *Excretolic acid*, and a fatty acid, having the properties of Margaric acid, but not constantly present.—"Proceedings of the Royal Society," vol. vii. No. 6.

the foregoing heads; on the contrary, it happens in some cases that a secreted product is of a mixed kind, partly excrementitious and partly recrementitious—partly rejected as needless or injurious—partly thrown off that it may subsequently fulfil a useful purpose in the economy of the individual and species. Thus the bile contains certain matters which are expelled with the excrements, while a large proportion of its elements is reabsorbed in the blood, after their commixture with the chyme in the intestines, and thus furnishes material for the production of animal heat in respiration.

The chief *secretions serving an ulterior purpose*, and which are thrown out with that object, are the following: The generative elements—the milk, the salivary, the gastric, pancreatic, and allied fluids; parts of the biliary fluid; the mucus from some surfaces; the epidermis and its appendages from the skin; the sebaceous and odoriferous matters from certain glands; the tears.

Water, as it forms a necessary part of the living frame, and is probably in constant course of formation within it, and as it is, besides, continually received in large quantities as food and drink, is a constant ingredient of the secretions, being thrown off especially by the lungs, skin, and kidneys. By the two former its loss is determined, in a great degree, by simple evaporation into the surrounding air; and this is necessarily influenced much by the hygrometric state and other conditions of that medium. By the latter, whose office is complemental of that of the preceding, a special apparatus is furnished for draining off the water, while this fluid is made useful in extracting the ingredients of the most important of the excretions from the surface over which it is subsequently made to flow.

Vicarious Secretion.—It has been remarked, that there is a sort of compensating action between the skin and kidneys in the normal condition of the system, dependent upon variations in temperature and other conditions. A similar power exists, in a more limited extent, in other secreting structures, by virtue of which one organ may take upon itself the work of another, whose healthy function has been temporarily suspended or impaired by disease. Advantage is taken of this circumstance in the treatment of kidney diseases, in which the functions of those organs are temporarily or permanently impaired. In such cases, the removal of the urinary constituents is promoted through the skin, or from the intestinal tube, by giving purgative medicines, and by promoting secretions. The excretion of biliary matter in the urine in cases of jaundice, and the separation of the menstrual fluid from the mucous membrane of the lungs or stomach, are familiar examples of this vicarious action. Very numerous cases of metastasis of the urinary secretion are on record; and elements of the urine have been met with in vomit, in the stools, in the tears, and secretions of the ears and nose; in the milk, and upon the cutaneous surface generally, particularly about the navel.

If the kidneys of an animal be extirpated, the elements of the urine may be detected in many situations in which they are not normally present. In disease, when the functions of the kidneys are

impaired, it is not uncommon for the elements of the urine to ›ff from the stomach by vomiting.

resta and Egesta.—It is obvious, that if the weight of the body ns the same, the quantity of matter removed by the different :ory channels will exactly correspond to the ingesta, although ·rangement of the elements will be changed.

› proportion in which the different elements entering into the ›sition of the food are removed by the various secreting organs wn in the following table, the result of some excellent experi- of M. Barral:

Ingested as Food.		Excreted.		
		In Urine.	In Fæces.	By Lungs and Skin.
. .	21,770·4 grs.	1060·7	798·3	19,911·4
›n . .	1,649·0	756·6	142·0	750·4
;en . .	8,370 6	218·1	122·0	8,035 5
ı . .	16,446·7	563·6	467·8	15,415·3
. .	48,286·7	2,594·0	1,580·1	39,112·6

› quantity of water removed from the body was usually one- ›r one-sixth more than that taken in, showing that water is produced in the organism.

neral View of the Anatomical Plan of Secreting Organs.—We said that the secreting tissues are arranged in such a manner › body as to have an external anatomical position, so as to be o set free the secreted product when formed. Some organs of :tly secreting kind, pour their material directly into the blood. ›ears most reasonable to regard the whole lymphatic system as paratus of this description, calculated not merely to restore to irculating current the superfluous or altered plasma, thrown by .pillaries into the interstices of the tissues, but destined by its ular parts especially to act on the passing fluid, and to pour t additional secreted matters, which pass by the efferent vessels ·nd with the general mass of blood. The inner surface of the ıatic vessels is here the external free surface, to which we refer .t from which the secretion is liberated.*

ain, there are other organs, viz., the synovial and serous ranes, which are usually and correctly classed as secreting s. They have been already described (p. 126). The fluid they e seems furnished for the purpose of lubricating their surface, to facilitate motion. It, consequently, does not leave the sur- n which it becomes free, but remains in contact with it, and ındergoes the same slow renewal and absorption, as all other and fluids with which blood in motion is brought into close ;nity. We have no reason to suppose that the effusions on these ›es suffer much deterioration by their continued contact. They r to differ but slightly from the serum of the blood, contain me saline matters in solution, and in nearly the same propor- The epithelium of these surfaces is no doubt concerned in

ıis view results from Professor Goodsir's anatomical researches, and from con- .ons which have been ably stated by Dr. Carpenter.—See *ante*, p. 615.

furnishing these fluids, but exerts little catalytic power over the liquor sanguinis, which, consequently, is little altered by being secreted. Mr. Rainey has well pointed out that the epithelium in certain situations is developed in a particular manner upon the projecting folds and fringes of synovial membrane, known as glands of Havers; and has shown it to be probable that the viscid synovia owes its origin chiefly to the surface of these parts. He has found this disposition not only in the joints, but also in the sheaths of tendons, and in the bursæ mucosæ.*

But, dismissing these structures, we arrive at that great system of parts, which we have before designated the mucous system, including, under one common title, the skin, mucous membranes, and true glands; the term *true glands*, meaning those which, by a duct, or otherwise, pour their secretion on the external surface, and not into the blood. For a summary account of the tissues forming this order of parts, the note at p. 522 of the present volume should be referred to. The skin, and most of the great regions of the mucous membranes, together with some of the glands, have been already minutely described in different parts of the preceding pages; and it now only remains, before passing to a description, in detail, of the great remaining glands, to offer some observations on the general plan or scheme of structure, discoverable in these special organs of secretion.

Between skin, mucous membranes, and glands, there exists every gradation of structure, by which one can be conceived to pass into the other. They are modifications of a common type. The two former are secreting organs, in an expanded form, sometimes presenting glandular involutions in their thickness. But, in proportion as the glands differ from mere membranes, we find them assuming a more solid form, gathered up, as it were, into a more compact mass, in which are to be still recognized all the elements of the simple membrane in their true relative positions—the free surface being still the free surface, though now forming, it may be the lining of ducts, and composing the internal tubular, or follicular recesses of the solid organ—and the deep, or vascular surface preserving the same relation as before to bloodvessels, lymphatics, nerves, or areolar tissue, under its various modifications. In particular the epithelium, or proper glandular tissue, remains capable by its anatomical position in regard to the external surface, to discharge its product on that surface. Thus the epithelium of the parotid gland, the liver, or the kidney, has such a relation to the remote parts of the excretory ducts of those organs, as that the secretion, resulting from the mutual action of that tissue and the blood, is set free into those channels, which are in reality, continuations of the integument, and therefore, in one sense, portions of the external surface of the body.

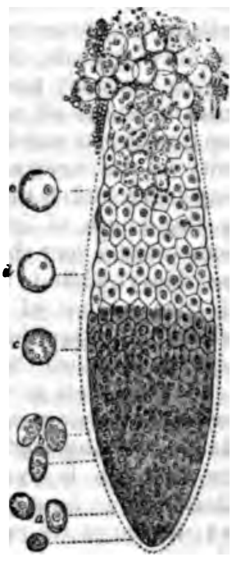
It will be readily seen how close and intimate must be, in all cases, the proximity of the glandular epithelium to the ducts. In fact, in many instances, the epithelium of the ducts is beyond doubt the

* Proceedings of the Royal Society, May 7, 1846.

secreting tissue, and the gland is a congeries of finely divided passages, or ducts, whose epithelium (though in a modified form) is directly continuous with that of the outer surface, on which the duct opens. This, for example, is the case in the sweat glands, in the sebaceous glands, already described (pp. 368, 369,), and in the kidney. But in other instances, whether owing to the form assumed by the terminal extremities of the duct, or to an actual difference in the arrangement of the glandular epithelium, the greatest difficulty exists in determining the exact nature of the anatomical relation of the glandular and ductal epithelium, and of ascertaining whether they are continuous at all times or only at certain periods when the secretion is discharged. For example, in the salivary glands, the pancreas, and some others, the terminal parts of the gland are vesicular, while the ducts are tubular. Vesicular terminations of the ducts may be rendered apparent by mercurial injection; but it is by no means easy to demonstrate the permanent continuity of the epithelium lining or filling these vesicles with that which lines the ducts.

It is probable that most or all gland follicles were originally closed vesicles. This has been shown by Dr. Allen Thompson to be the case in the early condition of the gastric glands; and Henle applies this view to other gland-structures. In his beautiful investigations upon the testicle of Squalus Cornubicus, Professor Goodsir has shown that the primary or mother cells are developed by the growth of isolated nucleated cells attached to the side of the duct. These cells grow and become the future acini, being connected with this duct by a hollow pedicle; in their interior, secondary cells, in which the spermatozoa are developed, appear. Still the mother cell is a closed cavity, and separated from the duct by its original wall. At length it gives way at this point and discharges its progeny of cells, containing spermatozoa, into the duct. The follicles then appear to become atrophied. There is another class of gland-structures in which, according to this view, the mother cell remains persistent after it has discharged its first progeny of cells, and continues to produce successive generations of cells; the development of these cells commencing at the cæcal extremity of the follicle. The point at which they originate is looked upon by Professor Goodsir as the persistent nucleus of the original parent cell; and it is termed by him, the "germinal centre." Although it is scarcely possible to demonstrate the existence of this germinal centre in the gland-follicle, there are many instances in which this view certainly appears to be borne out by the

Fig. 215.



Cæcal biliary tube of Cray-fish. At *a*, *b*, *c*, *d*, *e*, are shown cells in different stages as they advance from the lower part towards the outlet. After Leidy.

structure of the part when subjected to a careful microscopical examination. In the accompanying drawing of one of the cæcal tubes of the liver of the cray-fish (*astacus affinis*), after Leidy, the gradual transition from the granular matter at the bottom of the follicle to the perfectly formed cells which are being discharged from its summit is well seen.

In the glandules of Peyer, already described (*ante*, p. 581), it would seem that vesicles form underneath, but in immediate contiguity with, the mucous membrane, and, becoming filled with glandular contents, having the nature of nuclei, exhibit a great proneness to burst, and liberate their contents, perhaps periodically, on the free surface of the membrane. The ova, too, are very generally elaborated in the first instance in a matrix, or stroma, placed beneath, and not upon, the surface from which they are to be discharged. But notwithstanding these differences, which will be further considered, it must be borne in mind that the gland-cells, or secreting elements, in the true glands, are always so placed as to be able to discharge themselves or their products on the outer surface.

Of the Gland-Cell.—The gland-cells select and separate from the blood the substances which form their secreted product. These elements form, in fact, in a certain sense, a part of the food or pabulum of these secreting cells, which is set free when the cell has arrived at maturity, either by its rupture or by its complete detachment from the surface upon which it has grown, or, as occurs in other instances merely by transudation through its walls upon one side, while new matter is supplied to it from the plasma upon the other. Thus the function of secretion bears a certain analogy to nutrition. The cells in both processes select from the blood certain elements adapted for their growth; but in secretion, these separate products, after having probably undergone some changes in the cell, are destined soon to be cast off, and no longer form an integral part of the organism; while, in nutrition, these elements serve to keep up the integrity of the structure by which they have been appropriated. It may be remarked that the period of existence of the secreting cell, or the length of its life, varies considerably in different organs. Sometimes a very short time is sufficient for its development, growth and decay, while in other instances, it may persist for a long period of time. Some of the most important modifications of secreting cells will be described under the head of the glands, into the composition of which they enter.

Of the Ducts of Glands.—Ducts are tubular, usually branched passages, forming continuations between the secreting tissue of the glands and the surface of skin, or mucous membrane, on which the secretion is eventually poured. They are a contrivance by which a large mass of secreting tissue, packed in a small solid space, can discharge its product at a given point. They often present dilatations, wherein the secretion may be delayed for a time, and where, in many instances, it may undergo changes; and they very commonly contain a layer of unstriped muscle in their walls, by whose agency their contents are propelled in the proper direction,

against gravity. This contractile tissue is sometimes developed
ıeir orifice into a sphincter muscle. It is only the minuter
ls which open directly on a surface (*e. g.*, those of Lieberkühn
rew, in the intestinal mucous membrane), which are without a

ıe walls of ducts present most internally, an epithelium and
nent tissue, continuous with those of the skin or mucous mem-
. Outside, there are (when present) the muscular coat and
areolar tissue, which is prolonged upon their exterior in a
fied form. Bloodvessels and nerves ramify upon and within the
· coats. We owe the best description of the anatomy of ducts
enle.

e epithelium may vary from the scaly to the columnar or gland-
variety, and it is sometimes ciliated. The most common is the
mar, particularly in large ducts. In immediate connection with
roper mucous tissue, comes the muscular element, arranged in
ets of fibres, one longitudinal, the other circular, of which the
· can usually be seen to be the more internal. The fibrous ele-
s are commonly nucleated, and resemble those of the muscular
of bloodvessels; then follows areolar tissue, forming an outer
together with bloodvessels and nerves. The areolar coat gives
gth, toughness, and elasticity to the duct; the bloodvessels serve
s nourishment, and the nerves supply its muscular coat, and
v it with a peculiar sensibility, which, under particular circum-
es of pressure or detention (as in the passage of a biliary or
ry calculus), may rise to the height of the most exquisite pain,
ing fearfully on the whole nervous system.

e smaller ducts very generally are without muscular parietes,
are reduced to a homogeneous basement membrane, lined with
elium. Indeed, there is reason to believe that, in some cases,
ery smallest consist either of simple epithelium or of mere base-
tissue. The lobular passages of the lungs are an example of
atter constitution.

is not difficult to prove that the larger ducts are muscular.
, for example, the ureter. Open a small animal, just killed for
urpose, and this canal will be seen to present occasional peris-
contractions, passing rapidly from the kidney to the bladder,
ı may be easily excited by a mechanical or galvanic irritation,
y do not appear spontaneously. Besides this peristalsis, they
ıbtedly undergo, like the bloodvessels, a slow and uniform dila-
ı and narrowing, according to the bulk of their contents or
conditions.

some of those dilatations of the gland-ducts, which are provided
temporary reception of the secretion, such as the urinary blad-
nd the vesiculæ seminales, the muscular coat attains such a
ıess as to allow of being readily shown. The muscularity of
oats of the urethra was demonstrated, for the first time, some
ago, by Mr. Hancock. In the gall-bladder, muscle is certainly
oped to a far less extent; but even here, Dr. G. H. Meyer
that, by means of a powerful galvanic battery, he has caused

this receptacle in the ox to contract, so as to diminish its capacity one-fourth. The Fallopian tubes, uterus, and vagina, are parts rightly falling under the head of gland-ducts, though wonderfully modified in accordance with the functions they have to perform. The uterus in particular, under the condition of pregnancy, offers an example of the highest development of the involuntary or unstriped muscular fibre-cells anywhere met with.

We shall now proceed with a description of those glands which have not yet been treated of. Of those pertaining to the alimentary canal, the salivary glands and their secretion (p. 539), and the secretion of the pancreas (p. 592) and the liver (p. 600), have been already spoken of, and the structure only of the two latter remains to be considered. The kidneys and their secretion will follow; and we shall defer the consideration of the glands relating to the reproductive function to the chapters devoted to that subject. Such are the ovaries, the testes, the prostate, Cowper's glands, the mammæ.

The following works may be consulted upon the subject of secretion: Articles, "Secretion" and "Mucous Membrane," in the Cyclopædia of Anatomy and Physiology; "Anatomical and Pathological Observations," Professor Goodsir, 1845; "Lectures on Nutrition," Professor Paget; Medical Gazette, 1847; Principles of Human Physiology," Dr. Carpenter.

CHAPTER XXXIII.

SECRETING GLANDS.—OF THE PANCREAS.—OF THE LIVER.—THE LIVER IN INVERTEBRATA.—LOBULES OF THE LIVER.—PORTAL CANALS.—PORTAL VEIN.—HEPATIC ARTERY.—HEPATIC DUCT.—GALL BLADDER.—HEPATIC VEIN.—NERVES AND LYMPHATICS.—LIVER CELLS.—OF THE CONNECTION OF THE SMALLEST DUCTS WITH THE LIVER CELLS.—OF THE PASSAGE OF THE BILE INTO THE DUCTS.—OF THE QUANTITY AND USES OF THE BILE.

Of the Pancreas.—This is a large gland, placed across the spine, behind the stomach, in physiological relation with the duodenum or the first portion of the intestine. It is flattened from before backwards. Its left extremity, or tail, tapers off towards the spleen; its right extremity, or *head*, is much larger, lying close within the curve of the duodenum, and presenting a recurved extremity following the lower portion of that intestine, and sometimes termed the lesser pancreas. The ordinary weight of the pancreas, according to Cruveilhier, is from 2 to $2\frac{1}{2}$ ounces, but may rise to 6 ounces. Its colour is gray, inclining to pink.

The pancreas, like the salivary glands, is imbedded in areolar tissue, and receives its blood from several neighbouring vessels. Its arteries are derived from the splenic and hepatic branches of the

cœliac axis, and from the superior mesenteric. The blood is returned by the corresponding veins into the vena porta. Its nerves come from the solar plexus.

In structure, the pancreas appears to resemble the salivary glands. It is subdivided into lobules separated by septa of areolar tissue, which dip inwards from that which forms a common envelop to the whole gland. The lobules are subdivided into smaller parts by similar, but less complete and more delicate inflections of the areolar tissue; and these minute ultimate granulations or acini of the gland, correspond to the terminal extremities of the common duct. The excretory duct is concealed within the substance of the gland, and takes a course from the left to the right extremity, receiving very numerous tributaries on its way, and thus increasing in size, till it joins the common bile duct, close to its entrance into the duodenum. At its termination it is as large as a crow-quill. Its coats are thin and extensible, its internal surface smooth. It frequently happens that the duct belonging to the lower end of the curved portion or lesser pancreas opens separately into the intestine. In the rabbit the pancreatic duct opens by a separate orifice, sixteen or seventeen inches lower down the intestine than the bile duct (p. 595).

It is not difficult to inject the duct, and through it the ultimate secreting structure of the pancreas, with mercury. This may be best done in some of the smaller mammalia, where the glandular tissue is disseminated in lamellated grains between the layers of the mesentery, and where consequently the ramifications of the duct are naturally spread out towards the ultimate acini. The metal easily penetrates to these parts, and appears in the form of clusters of minute globules, having an average diameter of $\frac{1}{800}$ of an inch. These indicate, with probable truth, the terminal vesicles in which the duct ends, and which are lined with the epithelium, or true secreting tissue, continuous with that of the duct.

The vesicular terminations lie in the meshes of the capillary network, as is the case with the follicles of the salivary, and other conglomerate glands.

The secreting cells are more or less spheroidal in form, and vary somewhat in character according to their age. The mature cells are about the $\frac{1}{1800}$ of an inch in diameter, and are opaque, in consequence of being filled with numerous minute oil globules. The young cells are smaller than these, and are not so opaque.

The epithelium in the large ducts is of the columnar variety. The wall of the duct appears to be composed of fibrous tissue, in which elongated nuclei make their appearance upon the addition of acetic acid. The secretion of the pancreas has been described in Chapter XXV., p. 593.

Liver.—The liver is a large solid glandular organ, of firm consistence, of a dark reddish-brown colour. It measures about twelve inches from side to side, and six or seven inches from its anterior to its posterior border. According to the observations of Krause, the bulk of the liver corresponds to about eighty-eight cubic inches; its weight is between three and four pounds, and in the adult usually

amounts to about 1-36th of the weight of the whole body; but in the fœtus it is comparatively much larger. The female liver weighs somewhat less than that of the male. The specific gravity of the liver is about 1·05 in health.

The following is an analysis by Prof. Beale of a liver, presumed to be healthy. The organ was taken from the body of a man thirty-one years of age, who was killed by falling from a second-floor window, while in the enjoyment of perfect health.

		Per 100 of Solid Matter.
Water	68·58	
Solid matter	31·42	
Fatty matter	3·82	12·16
Albumen	4·67	14·86
Extractive matter	5·40	17·18
Alkaline salts	1·17	3·72
Vessels, etc., insoluble in water	16·03	51·01
Earthy salts	·33	1·05
	100·00	

In disease, the proportion of these constituents is liable to very great variation. In fatty degeneration, an enormous amount of fatty matter may accumulate in the organ. In one remarkable case, analyzed by Dr. Beale, the liver contained 75.07 per cent. of solid matter, and of this 65.19 consisted of fatty matter.* In scrofulous degeneration of the liver the albuminous materials and the water are increased, while the fatty matter is diminished in quantity.

The liver is situated in the right hypochondrium, and reaches over to the left, being thick and indented behind where it crosses the projecting bodies of the vertebræ, convex on its upper surface where it lies in the hollow of the diaphragm, and concave below where it rests against the stomach, colon, and right kidney. It is covered to a great extent by the peritoneum, the reflexions of which on to neighbouring parts, serve as ligaments to bind it in place, as well as to allow of the entrance and exit of the nerves and vessels, some of the latter being sufficiently large and strong to aid materially in the mechanical support of the organ.

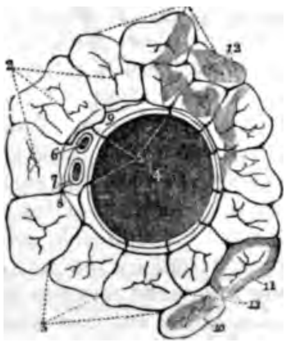
The liver is an unsymmetrical organ. In the fœtus, it is situated more equally on each side of the median line of the trunk; but in the adult the right side enormously preponderates, by the wasting or want of development of the left. It is still, however, divisible into a right and left lobe by the broad peritoneal ligament above, and by the longitudinal fissure beneath, both of these commencing in front by a notch in the border, across which passes, between the layers of the broad ligament, the cord-like remnant of the umbilical vein, and both tending towards the notch in the posterior border which lodges the vena cava; these divisions, however, are both of them on the surface only, and are rather vestiges of the imperfect conditions of fœtal existence than of value in the study of the physiological anatomy of the gland.

* Diseases of the Liver. Dr. Budd. Second edition, 1852.

On the under surface of the liver, is observed a groove passing off from the longitudinal fissure, transversely, for a certain distance, on the surface of the right lobe, and lodging the biliary ducts, the sinus of the vena porta, the hepatic artery, with lymphatics and nerves, all enveloped in areolar tissue, called the capsule of Glisson, and brought to this *transverse fissure* between the layers of the gastro-hepatic omentum. From this groove, there extends throughout the substance of the organ a series of tubular passages, so numerously ramified and uniformly distributed, that no part whatever of the hepatic substance is at a greater distance from them than about the thirtieth of an inch. These are called the *portal canals* (fig. 216), so named by Mr. Kiernan, because they lodge the *branches of the portal vein*, from which the plexus of capillaries surrounding the biliary-cells takes origin. The portal canals also lodge the bile-ducts, which are thus conducted to that aspect of the mass of bile-cells, where the capillary plexus commences. The same canals also convey the hepatic artery with the lymphatics and nerves of the liver.

On the posterior border of the liver already referred to, is a deep groove placed obliquely, *the fissure for the inferior vena cava;* from this there penetrate the substance of the organ, another series of ramified tubular passages, which are completely occupied by a nearly corresponding number of branches of the *hepatic veins*, or *venæ cavæ hepaticæ*, which open into the vena cava. These canals, called by the same distinguished anatomist, *hepatic venous canals*, are so distributed throughout the organ that some part of them comes within $\frac{1}{20}$ of an inch of every portion of its substance, and they are intermediate to the ramifications of the portal vein. The bases of the lobules adhere to these veins, and when they are cut across they do not collapse. The hepatic veins occupying these canals, throughout the organ, receive the blood of the portal vein after it has traversed the plexus of capillaries which envelops the series of biliary-cells.

Fig. 216.



A transverse section of a small portal canal and its vessels, after Kiernan. 4. Portal vein. 2. Interlobular branches. 5. Branches of the vein, also giving off interlobular branches, termed by Mr. Kiernan, vaginal branches. 7. Hepatic duct. 6. Hepatic artery.

This plexus of capillaries we therefore term the *portal-hepatic plexus.* It is a plexus containing venous blood, from which the bile-cells derive the materials which they secrete. The space which the blood passes over in traversing this plexus, in contiguity to the cells, is measured by the distance between the *ramified portal surface* and the *ramified hepatic venous surface* of the liver. The series of bile-cells discharge the bile into the biliary ducts on the portal side of the plexus, *i. e.*, where the blood is entering it, and their most remote parts commence on the hepatic venous side of it, *i. e.*, where the

blood is leaving it, so that the blood circulates in the reverse direction to that in which the bile must flow.

Fig. 217.

Human liver in which the portal vein (*d*) had been injected white, the artery (*e*) red, and the hepatic vein (*c*) lake; from the surface. Magnified 15 diameters. The capillary plexus is only shown in a few places. *a*. Portion of portal hepatic plexus. *b*. Portal hepatic plexus receiving at its peripheral surface small branches from the artery. *c*. Branches of the hepatic vein, interdigitating with the portal canals. *d*. Branches of the portal vein. *e*. One of the branches of the artery; some of its branches are seen ramifying upon the coats of the portal vein, and a few join the capillary plexus. Dr. Beale.

The Liver in Invertebrata.—The liver is one of the most constant glandular organs, being met with, in some form, in all animals provided with a digestive cavity. In the *polyps*, the liver is represented by some coloured cells round the stomach. In many of the *annelids*, clusters of biliary cells are seen surrounding the cæcal prolongations of the digestive cavity. In the Eolis (one of the nudibranchiate gasteropodous mollusks) a somewhat similar arrangement is observed, the follicles of the alimentary tube being prolonged into the papillæ, covering the dorsal surface of the animal. In most other *mollusks*, however, the liver exists as a distinct organ, and is composed of branched follicles, arranged round terminal ducts. The follicles contain coloured cells, in which oil globules are often present in considerable number. In many of the *crustacea*, the liver is detached from the intestinal walls, and consists of numerous large cæca (fig. 215), which pour their contents into small ducts, although in others it seems to consist simply of cells arranged in follicles, which are connected with the intestine, as in the lowest classes. In *insects*, the hepatic organ takes the form of simple or branched tubes, from two to six in number, which open into the intestine. According to our observations, the cells do not appear to be arranged round the tube, so as to leave a distinct central channel, as in the uriniferous tubule, but lie within the basement membrane, without order or regularity, often completely filling the tube, and not unfrequently, from their large size, causing it to bulge. We shall presently see that a

similar arrangement exists in the tubular network of basement membrane, which ains the liver-cells in vertebrate animals.

iroughout the whole animal series, the liver consists essentially of cells containing iring matter, and usually oil globules, which lie within a tube or follicle of base-; membrane, continuous with the alimentary canal.

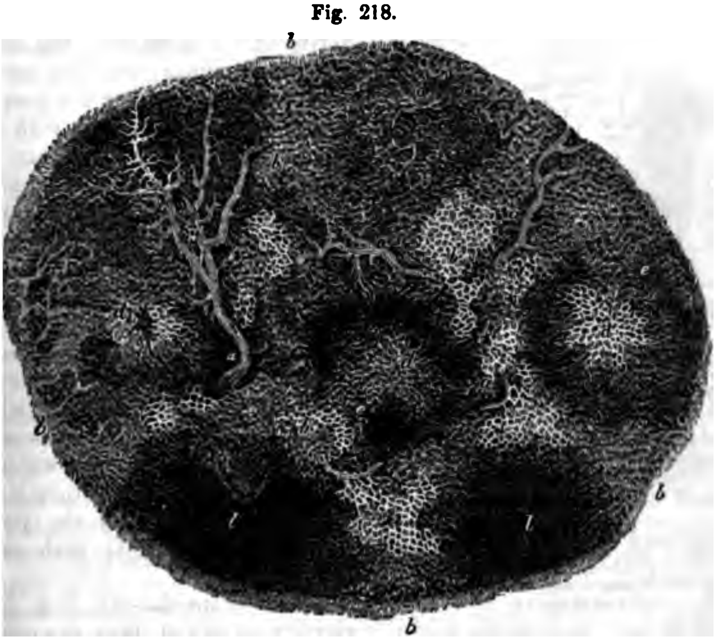
Iaving premised these general points, we shall now proceed to sider the anatomy of the liver more in detail.

;obules of the Liver.—The terminal twigs of the portal veins and commencing radicles of the hepatic vein, thus distributed through liver with a definite thickness of capillary plexus with nucleated -cells interposed, are further arranged in a a manner as that the intervening mass athered, not into a folded sheet, but into ;reat number of small portions, termed *iles.* These lobules are apparent to the in many animals; but in the pig they are h of them invested by a separate and inct membranous envelope or capsule, ch is composed of delicate fibrous tissue . 218). In this animal, each lobule may 'egarded as an isolated and separate liver, the whole gland as an agglomeration of ller ones, connected by the penultimate aches of the portal vein, artery and duct, which run between the

Fig. 218.

Portion of fibrous capsule of a lobule of the pig's liver, showing arrangement of the fibres—215 diameters.

Fig. 218.

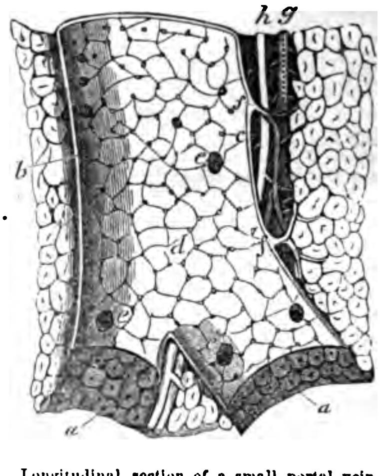


ules of a cat's liver partially injected through the portal vein, and also through the hepatic *a.* Twigs of portal vein. *b.* Capillaries springing from them, which serve to mark the outline lobules. *d.* Capillaries in the centre of the lobules injected from the hepatic vein. *e.* Situa-at which the injection forced into the two vessels has met. *l.* Central parts of lobule not ed.

lobules, and by the areolar tissue which accompanies them; but not by any inosculation or coalescence of the ultimate secreting elements, the liver-cells, or the capillaries. In other animals, and in the human subject, the lobules are not thus isolated, but are only imperfectly marked out by the several points of their exterior, to which the ultimate twigs of the portal vein and duct arrive. The twigs of the vein terminate in a plexus of capillaries common to all the contiguous lobules, and continuous between them, so that the lobules themselves have no definite limit (fig. 219), but blend with each other, except at certain points of their exterior. It is not likely that these differences in the isolation of the lobules in various animals are of any physiological importance, but they have, probably, given rise to much of the difference of opinion which exists among anatomists on this subject.

The shape of the lobules, whether completely defined by an investment of fibrous tissue, or merely mapped out by the position of the several twigs of the portal vein, hepatic artery, and duct, may be said to be determined by the mode of distribution of these vessels. The *intralobular* hepatic vein occupies the central axis of the lobules, and usually consists of a stem, into which three to five, or even more, subordinate twigs empty the blood derived from the capillary plexus. The lobule is elongated on this vein, and presents a process for each of the subordinate twigs.

Fig. 220.



Longitudinal section of a small portal vein and canal, after Kiernan. *a.* Portions of the canal from which the vein has been removed. *b.* Side of the portal vein in contact with the canal. *c.* The side of the vein which is separated from the canal by the hepatic artery and duct, with areolar tissue (Glisson's capsule). *d.* Internal surface of the portal vein, through which is seen the outline of the lobules and the openings of the interlobular veins. *f.* Vaginal veins of Kiernan. *g.* Hepatic artery. *h.* Hepatic duct.

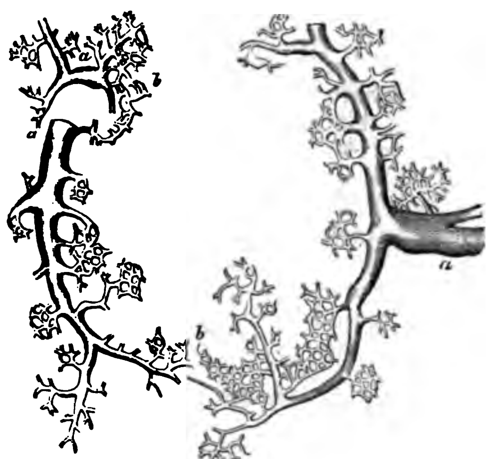
In all cases, the terminal branches of the portal vein and the duct arrive at the surface of the lobule at several points; and the surface of the lobule, whether complete or incomplete, is continuous with that of the portal canals. From this surface, in all cases, the capillary plexus tends, by the slight elongation of its close meshes, and converges towards the intralobular hepatic vein in the axis of the lobule. It probably follows that, in this latter situation, the blood, after having been nearly deprived of those constituents from which the bile is formed, circulates more rapidly than at the more external parts of the lobule, whither it has just been brought by the portal veins, richly charged with these constituents.

Portal Canals.—It has been already observed that the portal canals contain a branch of the portal vein, with a branch of the hepatic artery and of the biliary

duct; not unfrequently the vein is accompanied by two branches of the artery and duct.

The branches of the artery and duct are connected with those of the portal vein by areolar tissue, which is abundant in the transverse fissure of the liver, and in the larger portal canals, but in the smaller exists chiefly on that side of the vein where the artery and duct lie; while, as the vessels diminish in size, the amount of this areolar tissue becomes less until it entirely ceases, where the small branches which supply the lobules are given off. This investment of areolar tissue, described under the name of Glisson's capsule, from its dis-

Fig. 221.



A small lobule from the pig's liver, showing *a*, the interlobular branches of the portal vein, and *b*, a portion of the lobular capillary network within the capsule injected. Each branch is seen to give off small branches on either side to the adjacent lobules. After Dr. Beale.

coverer, has been stated, by many subsequent writers, to be prolonged into every part of the gland, separating the lobules from each other, and forming an investment for each—a description which we have failed to verify in every mammalian animal which we have examined except the pig, where this areolar tissue is really prolonged between the lobules.

Portal Vein.—The large portal vein is formed by the union of the veins of the stomach and intestines, the pancreatic and splenic veins, and the veins of the mesentery, omentum, and gall-bladder. The portal circulation has been described in p. 676, and we have, therefore, only to describe the distribution of the vein in the liver. The branches of the portal vein may be said, in general terms, to be arranged round the lobules; but the branches upon different sides do not anastomose so as to encircle each lobule with a venous ring, as many authors, following Kiernan's diagram, have described and represented, but communicate with each other only through the intervention of capillaries. Even in the pig there is no vascular ring,

although to the naked eye it might appear so. In the liver of the human subject, and in livers allied to it, small branches of the portal vein can often be traced from the interlobular fissures into the lobule, breaking up into capillaries as they go. The arrangement of the branches of the portal vein round one of the smallest lobules of the pig's liver, with a few of the lobular capillaries injected, is shown in fig. 221.

Hepatic Artery.—Many branches of the artery pass to the capsule of the liver, in which they ramify abundantly, forming a network, having large meshes. These *capsular* branches and their anastomoses, are readily injected in the liver of the fœtus or child.

The artery gives off numerous branches in the portal canals. The greater number of these are distributed upon the coats of the ducts. The thick walls of the larger ducts are abundantly supplied with arterial blood; but the smaller branches of the duct, the coats of which are extremely delicate, pass through the meshes of an arterial network. In the pig, this network may be demonstrated upon the surface of each lobule (fig. 222), but in the human subject, the branches are less numerous, and are seen only in the interlobular fissures; other branches supply the coats of the portal and hepatic veins. The greater quantity of blood, after passing through these small arteries, is collected by venous radicles, which empty themselves into the branches of the portal vein. A few very small arterial branches may be traced from the portal aspect of the lobule for a short distance into its interior, where they join the portal hepatic

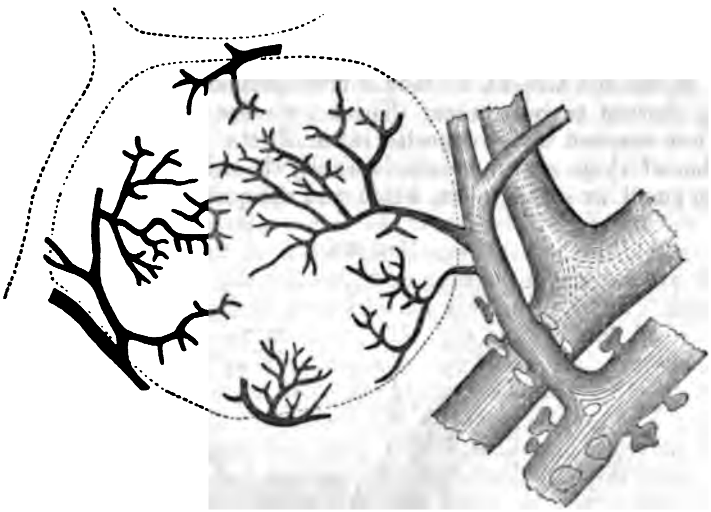
Fig. 222.

a. Part of arterial ring, with branches ramifying upon the capsules of the lobules of the pig's liver. *b.* Arterial network. *c.* Portion of lobular capillary network injected from the artery, and small branches of the latter entering it. After Dr. Beale.

plexus of capillaries. The whole of the arterial blood, therefore, which supplies nutriment to the several structures of the liver, passes through the capillaries of the lobule before it is returned to the heart, and no doubt furnishes a small portion of the matters from which

the bile is formed. The artery was rightly regarded by Kiernan as one of the sources of the blood conveyed to the secreting structure of the liver, by the branches of the portal vein.

Fig. 228.



A small lobule, showing the duct branching upon the capsule, from the pig. The sacculi of the ducts are injected in this specimen. The vessel accompanying the duct is a branch of the portal vein.

The gall-bladder is also supplied largely with arterial blood. The arteries are arranged so as to form a beautiful network. Each branch of the artery is accompanied by two branches of the vein, one on either side, and when the arterial and venous networks are injected with different colours a most beautiful appearance is produced. A similar disposition of arteries and veins occurs in the transverse fissure, and also in the large portal canals. This arrangement has probably the effect of insuring free circulation through the veins in those changes of size and position to which the vessels are liable.

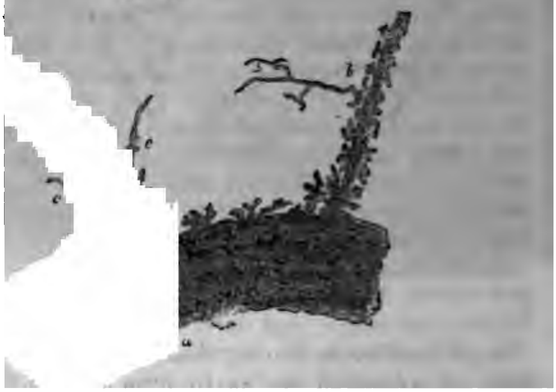
Duct.—At least one branch of the duct accompanies each branch of the portal vein, but frequently there are two or three. From the branch or branches accompanying the vein, several smaller ones pass off to the secreting structure. In the pig, the interlobular ducts, while running between contiguous lobules, are applied, as it were, to the exterior of their capsules, and give off much smaller twigs on either side, which perforate the capsules, and become connected with the cells in the manner presently to be described.

Parietal Sacculi and Appendages of the Ducts.—In ducts of about the $\frac{1}{125}$ of an inch in diameter, and larger, there are many little saccular dilatations situated in the coats. These are the so-called glands of the ducts, and in the pig, and most other animals which we have examined, are arranged all round the tube. Dr.

Beale, who has examined them with great care, describes them as, for the most part, simple oval pouches connected with the cavity of the duct by a very narrow neck, often not the $\frac{1}{5000}$ of an inch in diameter. In the larger ducts, they are branched, and often run for some distance in the coats. Occasionally, the branches of one gland anastomose with those of another. The largest are singularly complicated, and project some distance from the duct lying in the areolar tissue which surrounds it. Fig. 224.

In the human subject, a different arrangement occurs. Instead of being situated entirely round the tube, the openings form two rows or lines situated upon opposite sides of the ducts. The greater number of these openings are, however, the orifices, not of sacculi, but of small irregular tubes, which run obliquely for some distance

Fig. 224.



a. Portion of a large duct of the pig, injected with vermilion, shewing the large cavities or glands in the coats of the ducts. The largest and most complicated are represented at *c*, just at the point where a smaller branch is coming off from the trunk of the duct. *b.* A small branch without glands. Magnified about ten diameters. From a drawing by Dr. Beale.

in the coats of the duct and anastomose; some of these branches leave the ducts anastomose with each other just outside the trunk from which they are given off.

Many of the small ducts about the $\frac{1}{80}$ of an inch in diameter, have numerous cæcal pouches connected with them, arranged pretty close together, gradually becoming shorter as the duct becomes smaller, and giving off branches composed of basement membrane only. These irregular ducts with cæcal pouches are very numerous in the transverse fissure of the liver, where they form an intricate network connected with the larger branches of the duct in this situation. These were described by Theile as branching mucous glands, but were first noticed and named *vasa aberrantia* by Weber, who also described the anastomosis between the right and left hepatic ducts in the transverse fissure, by the intervention of these irregular branches.

In the portal canals, the vasa aberrantia occur as already mentioned, but in diminished number. Dr. Beale considers these cavi-

ties, or irregular branches, connected with the ducts, as little reservoirs in which the bile in ducts with thick coats is brought into closer proximity with the numerous vessels surrounding them, by which means it loses some of its water, and probably undergoes other changes. He observes, that the arrangement of the vessels around these ducts, both in the transverse fissure of the liver and in the portal canals, is similar to that which exists in the coats of the gall-bladder. A small cavity with a narrow neck seems scarcely adapted for pouring out viscid mucus; moreover, the bile of animals, in which these so-called glands are very few in number, as in the rabbit, seems to contain as much mucus as that of the pig, in which animal the glands are very numerous and well developed. According to this view of their office, these cavities may be regarded in the light of little gall-bladders.

The coats of the larger ducts appear to be principally composed of condensed fibrous tissue, but there is reason for supposing that, at least in some of them, there are a few muscular fibre cells, although they do not form a distinct layer or muscular coat.

The epithelium of the larger ducts is of the columnar variety. The cells are large and well formed, often exhibiting a distinct nucleus. They are frequently tinged with yellow colouring matter, and often contain yellow granules. In the smaller ducts, this epithelium becomes shorter, until, in the smallest branches, it approaches more nearly to the tesselated variety.

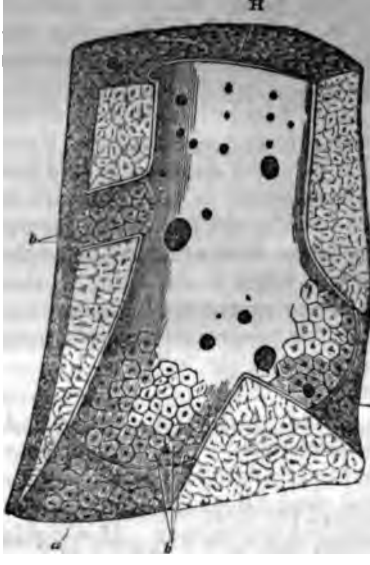
Gall-Bladder.—The gall-bladder may be looked upon as a diverticulum of the hepatic duct. It lies in a fossa underneath the liver. It is of a pear shape, and its fundus is directed downwards and forwards; it terminates in the *cystic duct*, which is about an inch in length. The *hepatic duct*, leaving the liver by the transverse fissure, passes downwards, and soon joins the cystic duct at an acute angle, to form the *ductus communis choledochus*, which is about three inches in length, and lies between the layers of the gastro-hepatic omentum. After coming into close proximity with the pancreatic duct, the common duct enters the coats of the intestine with the latter, and passes obliquely between them for three-quarters of an inch. The ducts open by an orifice common to both at the junction of the descending and transverse portions of the duodenum. The mucous membrane of the gall-bladder is thrown into reticulated folds, which form the boundaries of numerous polygonal depressions, so that upon its internal surface it presents a honeycombed appearance. It is highly vascular, and is covered with columnar epithelium. The folds are prolonged into the cystic duct, where they are arranged in a crescentic manner, their general direction being that of a spiral, and they have been compared to a spiral valve. The peculiar arrangement of the vessels of the gall-bladder has been already referred to. The cystic artery is derived from the right division of the hepatic, and the veins empty themselves into the vena portæ. The lymphatics are very numerous. The greater part of the thickness of the walls of the gall-bladder is composed of fibrous tissue, but there also exists a thin layer of delicate muscular fibre cells, which take partly a

longitudinal and partly a transverse direction. The human gall-bladder is capable of containing about an ounce of fluid, but it undergoes great alterations in volume, and in it the bile becomes inspissated, and probably undergoes other changes.

This viscus is absent in many genera of fishes; in pigeons, toucans, and some other birds; in the elephant, stag, horse, and tapir; but it is present in the ox, sheep, and antelope. It is always found amongst reptiles. The reason of its absence in the animals above alluded to is not yet satisfactorily explained.

Hepatic Vein.—The branches of the hepatic vein run in channels, which are situated between the portal canals (fig. 217), and in consequence of the small quantity of areolar tissue surrounding the hepatic vein, the bases of the adjacent lobules are in contact with it, so that when a branch of the hepatic vein is cut across, it does not collapse, but remains open. The small twigs which collect the blood from the lobules surrounding the trunk of the vein open at once into it, except in the case of the largest branches, where the coats are very thick. This arrangement is shown in fig. 225, after Mr. Kiernan. In this drawing the openings of the small branches of the *hepatic* vein (intralobular vein) are seen in the centre of each lobule, while in fig. 220, which represents a *portal* vein laid open, the orifices of the smallest branches are seen in the spaces between two lobules (interlobular veins).

Fig. 225.



Longitudinal section of an hepatic vein. *a.* Portion of the canal from which the vein has been removed. *b.* Orifices of ultimate twigs of the vein (intralobular) situated in the centre of the lobules, after Kiernan. Compare the arrangement of the small veins in this figure with the branches of the portal vein in fig. 220.

The capillaries in the central part of the lobule open into the small twig of the hepatic vein upon all sides. These points are well seen in the pig's liver, where the lobules are distinct, but in the human and other livers, the arrangement varies slightly in consequence of the lobules communicating with each other in the intervals between the interlobular fissures (fig. 217).

Nerves and Lymphatics.—The nerves of the liver are derived chiefly from the sympathetic, but a few branches of the vagus are also distributed to the organ. They consist of tubular and gelatinous nerve fibres, and are distributed principally upon the walls of the artery over which they form a network.

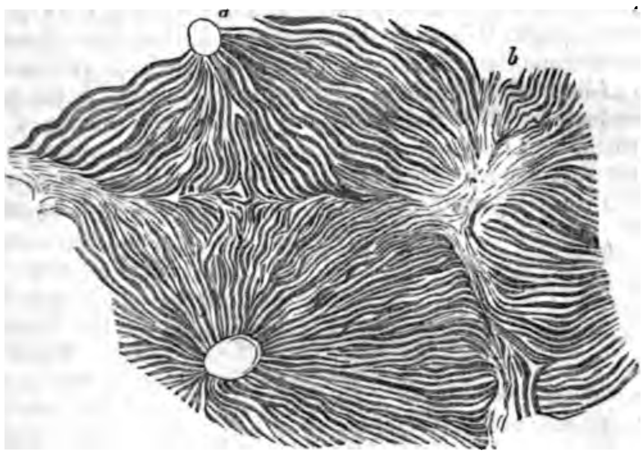
Branches may be traced into Glisson's capsule, and to the coats of

the gall-bladder and larger ducts, as well as to the coats of the larger branches of the hepatic vein.

The lymphatics are found in considerable abundance in the liver; they are distributed to the gall-bladder, and form a network upon the surface of the organ underneath the peritoneum. An abundant network of lymphatics exists in the largest portal canals, and when the ducts are injected, it not unfrequently happens that a small branch bursts, and the injection escapes into the lymphatics. In this way, some lymphatic glands near the liver are often injected, and the injection sometimes even reaches the thoracic duct, as occurred to Mr. Kiernan, and also to Dr. Beale.

Of the Liver Cells.—From what has been already stated, with regard to the arrangement of the solid capillary venous plexus of the lobules, it will be inferred that the cells occupy the meshes of this network. It has long been a question whether the cells lie amongst these capillary vessels, or are enclosed in a basement membrane, as we should expect from the analogy of other glandular organs. It has

Fig. 226.



Section of horse's liver, at right angles to branches of the hepatic vein, showing the cells forming lines radiating from the centre towards the circumference of the lobules. From a preparation of Dr. Beale's.

been admitted by all who have examined the liver carefully, that in sections made in a particular direction, the cells are seen to form lines which radiate from the centre towards the circumference of the lobule; these lines being connected with oblique or transverse branches. Such an appearance is not presented in every section, but only in those made exactly at right angles with the small twig of the hepatic vein. This is well seen in fig. 226. The cells are described by Kölliker and others, as being placed end to end, forming solid cylinders, but not invested with basement membrane. Usually there is only room for one row of cells; but in some situations, two or three

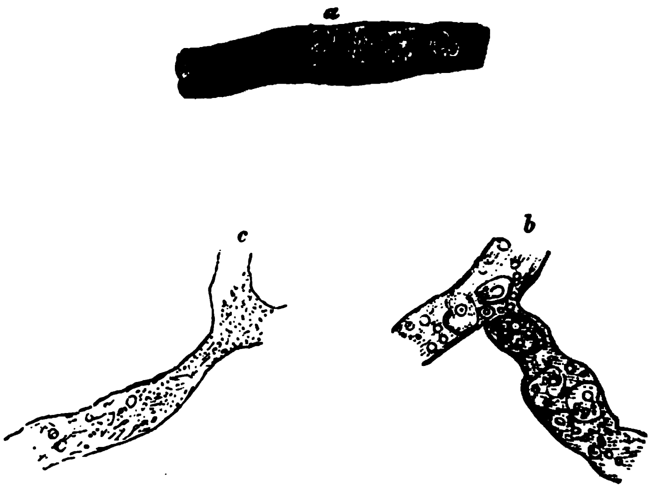
may be seen between two capillary vessels. Dr. Handfield Jones has been led by his researches to adopt the same conclusion with regard to the arrangement of the liver cells, and Dr. Carpenter has expressed himself in favour of a similar view.

On the other hand, Retzius, Leidy, and some other observers, advocate the presence of a tubular basement membrane, in which the cells lie, and which is continuous with the hepatic ducts.

The minute anatomy of the liver has lately been subjected to a careful investigation by our friend and former pupil, Dr. Beale; and we believe he has established the existence of this basement membrane by several different methods of preparation. His observations have been made upon injected as well as uninjected preparations. The membrane is so exceedingly delicate, that it can be demonstrated alone by the granular matter which adheres to it. Dr. Beale has succeeded in injecting the tubular network in which the cells lie; and the injection has been seen to pass round the cells, separating them slightly from each other. When the cells are broken down by the action of chemical reagents, the outline of the tube can often be seen distinctly. This delicate basement membrane in most situations appears to be incorporated with the walls of the capillaries, but in some places it is to be demonstrated distinct from them.

Not unfrequently cells are met with in the fluid surrounding a section of liver with shreds of membrane attached to them; and in a few rare instances this membrane may be seen in the form of a tube, in which the cell is evidently contained. Injection, however, affords the most satisfactory proof of the existence of this basement membrane. In well-injected specimens the outline of the tube in which

Fig. 227.



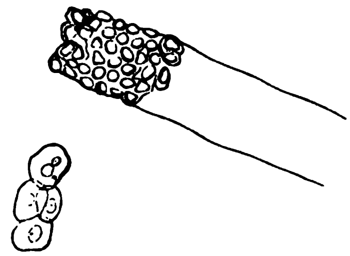
Portion of tubular network of basement membrane in which the liver cells lie, *a.* from an injected specimen—the shaded portions show the position of the injection. *b.* Cells and free oil globules lying within the tube. *c.* Specimen in which the cells have been disintegrated. From the pig; 215 diameters. After Dr. Beale.

lls are contained can be seen in some parts of the lobule, sepa-
from that of the capillary vessels.*
liver cells may be broken down in some specimens, and the
r membrane contain only granular matter suspended in fluid,
resented in fig. 227 *c*.
peculiar and characteristic cells of which the substance of
er is chiefly composed, are of a more or less spheroidal form,
'ten somewhat flattened and many-sided from mutual com-
›n.
y vary from the $\frac{1}{1000}$ to the $\frac{1}{2000}$ of an inch in diameter, and
mes even smaller. Their surface is smooth, and their outline
:t and well defined. Each contains a distinct nucleus in the
r, and occasionally cells may be observed with two nuclei. In
cleus a highly refracting nucleolus, with several granules, can
r be distinguished.
contents of the cell appear to be of a firm viscid consistence,
t when pressed between glass, the contents do not escape sud-
but the whole cell becomes flattened. Usually there are, in
;erior, several oil globules, which, as regards size and number,
bject to great variations. In some cells the entire cavity is
ed by globules, in others not one can be observed; besides oil
es, distinguished by their light centre and dark well-defined
›, the cell contains in its interior numerous amorphous granules,
may vary in size from a scarcely visible dot, to a particle as
ıs a blood globule, or even larger. Granules of a bright yellow
, composed of biliary colouring matter, are often met with, but
occur constantly. In cases of jaundice from obstruction of
ıct, the number and size of these coloured particles often in-
to an enormous extent, so that the cell appears to be entirely
ed with them, and in extreme cases no distinct cells whatever
detected.
ıighly fed animals, and in that condition termed fatty degene-
of the liver, so common in cases of phthisis, the cells seem
entirely occupied by large oil globules, without any coloured
es. The cells at the portal aspect of the lobule usually con-
ıost oil, while those in the centre contain a greater number of
ɔd granules, but frequently these yellow granules are present
cells in both situations.
dilute caustic soda, or potash, the cells swell up and become
.nd of a more rounded form; after a short time they are dis-
, unless the solution is very weak. Acetic acid produces a
hat similar change, but the cell membrane does not appear to
ıolved. The nuclei always appear more distinctly defined after
dition of the acid; cells which, at first, were found to contain
ɔured granules, by being soaked for some time in dilute acetic
ɛhibited many.
the smallest Branches of the Hepatic Duct and of their Con-
ı with the Hepatic Cells.—Of the manner in which the ducts

ɜse specimens were prepared by injecting the ducts with Prussian blue, and
al vessels with plain size.

commence in the liver, there has been much difference of opinion, and the most conflicting views have been entertained. Mr. Kiernan considered that the ducts commenced in a lobular plexus although he was never able to prove the existence of such an arrangement. Kölliker gives a diagram to illustrate his view, which supposes that the open ends of the ducts impinge against the columns of the hepatic cells at the margin of the lobule. Dr. Handfield Jones traces the ducts to the same point, where, he believes, they terminate without having any direct communication with the hepatic cells; and he considers that the small cells in these ducts are alone concerned in the secretion of the bile (fig. 228). If this view of the anatomy of the liver be correct, this large organ must be nearly related to the vascular glands.*

Fig. 228.



Terminal portion of interlobular duct, with epithelium within it. Four hepatic cells to show relative size. To illustrate Dr. Handfield Jones' view.

Dr. Beale's researches show that Mr. Kiernan's original view is more nearly allied to the truth.

In the interlobular fissures numerous finer branches leave the small trunk of the duct and pass towards the secreting cells. In the human subject, many of these may be followed for some distance without giving off branches or anastomosing with each other. These small ducts lie around the small branches of the portal vein, and their course is often tortuous.

In some animals, particularly in the rabbit, the small ducts anastomose, forming a network round the vein. This network is continuous with the network of the lobule in which the cells lie. In the human subject, and in most mammalia, the small ducts do not form a network in this manner, but pass off at once to the cell-containing network with which they are continuous. In the pig, the smallest branches of the duct penetrate the capsule of the lobule at various points, and immediately become connected with an intimate network which lies immediately beneath it, and partly within its substance. This network may be regarded as the most superficial portion of the cell-containing network, and where the liver is fatty it contains cells distended with oil globules.

In the human liver, and in those of most animals, except the pig, some of the smallest branches of the duct pass for a short distance beneath the surface of the lobule, and become continuous with some of the branches of the cell-containing network in that situation. In a cursory examination these narrow ducts appear to lie amongst the cells without being connected with them. The greater number of

* Vide Kölliker's Manual of Human Histology, translated by Busk and Huxley: Sydenham Society, 1853–54. Dr. Carpenter's General and Comparative Physiology, 4th edition.

branches, however, join the cell-containing network round the margin of the fissures.

Near to the point where the duct joins the cell-containing network it becomes very much narrowed, and is often not more than the $\frac{1}{4000}$ or $\frac{1}{5000}$ of an inch in diameter, and even less, in the uninjected state. Several of the narrowest ducts in the pig are represented in fig. 229.

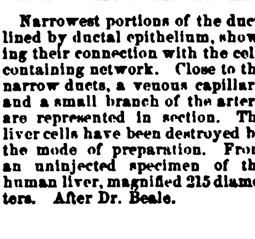
Fig. 229.

a. Small branch of interlobular duct—pig. *b*. Most superficial part of cell-containing network, with cells filled with oil, and free oil globules. *c*. Narrowest portions of the duct. Magnified 215 diameters. The shaded parts show the points to which the injection reached. After Dr. Beale.

Fig. 230 represents some of the small ducts and a part of the cell-containing network at the surface of a lobule in the human liver. The cells have been nearly destroyed by the action of reagents in preparing the specimen.

The epithelial cells which line these minute ducts approach to the tesselated variety. They are, for the most part, round or oval granular cells, some of them about the $\frac{1}{5000}$th of an inch in diameter, while others are less. They present very similar characters in the different animals which we have examined, and the same general arrangement of the minute ducts has been shown to occur in birds, reptiles, and fishes, with certain unimportant modifications.

Fig. 230.



Narrowest portions of the duct, lined by ductal epithelium, showing their connection with the cell-containing network. Close to the narrow ducts, a venous capillary and a small branch of the artery are represented in section. The liver cells have been destroyed by the mode of preparation. From an uninjected specimen of the human liver, magnified 215 diameters. After Dr. Beale.

The epithelium of the ducts does not pass by gradations into the secreting epithelium, but terminates at the point where the latter commences. The narrowing of the excretory portion of the tube is met with in many other glands, but in none is there a more striking contrast between the excretory and secreting portions of the gland, or between the epithelium lining the ducts and that by which the secretion is formed, than in the liver.

Of the Passage of the Bile into the Ducts.—If the view of the anatomy of the liver which we have described be correct, the secreting cells at the surface of the lobule are those which take the most active part in the secretion. These are the cells which the portal blood first reaches; and it is in this situation that the cells first show an increased quantity of oil globules within them in cases of fatty degeneration. The bile is not formed in the central part of the lobule, and transmitted from cell to cell, as has been described by some authorities, but the bile formed by each individual cell escapes through the interstices between the cells until it reaches the duct. If it be urged, as an objection to this view, that no visible interstices exist between the cells, it may be answered that injection can be made to flow by these channels in a direction the reverse of that which the bile naturally takes, and, therefore, under the greatest disadvantage. There can then be no obstacle to the passage of the bile towards the ducts; moreover, the great changes in bulk, which we know the liver cells so readily undergo, will readily account for the close contact in which they are often observed to lie.

From a careful consideration of the anatomy of the parts, we should be led to look upon the liver as a large gland, in which a considerable quantity of a highly elaborated secretion was slowly formed, and slowly transmitted in a more highly concentrated form towards the intestine. The arrangement of the vasa aberrantia and of the little cavities in the coats of the thick-walled ducts, the abundance of vessels and lymphatics in such close proximity to the ducts, and the great similarity of their disposition with that of the vessels of the gall-bladder, where we know absorption of fluid takes place, favour the idea that important changes occur in the bile after its formation by the cells of the liver.

The liver is, therefore, a true gland, consisting of a formative portion and a system of excretory ducts directly continuous with it. The secreting cells lie within a delicate tubular network of basement membrane, through the thin walls of which they draw from the blood the materials of their secretion.

Quantity and Uses of the Bile.—We have already considered the composition and uses of the bile in Chapter XXV.; but since that part of our work was published, some important results have been communicated by Bidder and Schmidt, which we shall here briefly allude to.*

These excellent observers have concluded, from numerous experiments upon different animals, that the quantity of bile secreted during the twenty-four hours is much larger than had been supposed. Cats secreted 14.5 grammes, dogs nearly 20 grammes, and sheep 25 grammes, for each kilogramme (about 2 lbs. 3 oz. avoirdupois) in the weight of the animal. From these data, it is of course, difficult to draw a correct inference as to the quantity of bile secreted by the human subject; but, from calculating from these results, it has been

* Die Verdauungssaefte und der Stoffwechsel von Dr. F. Bidder und Dr. C. Schmidt. Mitau und Leipzig, 1852.

red probable that an adult man secretes about 54 oz. of pure ı the twenty-four hours, and this contains about 2½ oz. of solid r. This estimate is very much higher than that which we have at p. 597.

e activity of the secretion varies greatly at different periods of ay. For one or two hours after a meal, it is very small in nt; but from this time, it gradually increases until it attains its num, about the fifteenth hour after the last meal. The secre- hen rapidly diminishes in quantity, until it is not more than it wo hours after the meal. The gall-bladder empties itself about nd a half or three hours after taking food.

appears that an exclusively amylaceous, or fatty diet, causes a diminution in the secretion of bile, while a pure flesh diet es a very abundant secretion.

e presence of bile very much promotes the absorption of fatty r, although a certain quantity of fat is absorbed even if no bile s the intestine. The presence of bile causes the absorption of nd a half times more fatty matter than would be absorbed with- . Bile appears to render the mucous membrane more perme- o fatty matter.

lder and Schmidt consider that the chief object of the bile is prolong the series of changes to which animal matter is sub- l within the organism, and thus to render it for a longer time nt in the discharge of vital processes."

he Pancreas, consult article "Pancreas" in the Cyclopædia of Anatomy and logy, by Dr. Hyde Salter. Upon the anatomy of the Liver, the following works referred to: Kiernan, "The Anatomy and Physiology of the Liver," Phil. , 1833; Theile, Art. "Leber," im Wagner's Handwörterbuch der Physiologie; "Liver," by Mr. Wilson, in the Cyclopædia of Anatomy and Physiology; in the American Journal of the Medical Sciences; Kölliker's Mikroskopische nie; Beale, "On the Ultimate Arrangement of the Biliary Ducts, and on some Points in the Anatomy of the Liver of Vertebrate Animals," Phil. Trans. 1856.

CHAPTER XXXIV.

TING GLANDS.—THE KIDNEYS.—PARENCHYMA.—MATRIX.—URI- FEROUS TUBES.—MALPIGHIAN BODIES.—CONVOLUTED PORTION THE URINIFEROUS TUBE.—STRAIGHT PORTION.—VESSELS OF THE DNEY.—OF THE SECRETION OF URINE.—URINE.—QUANTITY.— ACTION.—CHEMICAL COMPOSITION.—UREA.—URIC ACID.—HIP- RIC ACID.—CREATINE.—CREATININE.—EXTRACTIVE MATTERS.— MONIACAL SALTS.—FIXED SALTS.—CHLORIDES.—SULPHATES.— OSPHATES.

XT in size and importance to the liver, are the kidneys. These s are symmetrical organs, one being placed on each side of the in the lumbar region. In consequence of the position of the

liver, the right kidney is placed rather lower down than the left. These organs are surrounded by a varying quantity of fat, and are placed behind the peritoneum. The kidney is of a dark reddish-brown colour, of a firm consistence, and of a close compact texture. Its general form is that of an ordinary French bean, compressed from before backwards, its convex border being external, and its concave edge, or hilum, where the vessels enter, looking towards the median line. The weight of the healthy kidney is from 4½ to 5 oz. in the male, and somewhat less in the female. The kidneys are supplied with blood by the renal arteries, two large trunks which come off at right angles from the abdominal aorta. The blood is returned by the large renal or emulgent veins which open into the inferior cava. These vessels, with the nerves for the supply of the organ, enter the kidney at its notch or hilum, whence also proceeds the ureter.

Of the Kidney in the lower Animals.—The first trace of an organ which can be regarded in the light of a kidney is met with among the *Polypi*, but the renal nature of this is at least doubtful. In *Porpita*, one of the *Acalephæ*, Kölliker has described an organ which contains guanin, and which he therefore looks upon in the light of a kidney. In the *Annelida* the existence of a renal apparatus is doubtful; but there is some reason for believing that the so-called respiratory organs are to be regarded in this light. The existence of these glands is not determined in the *Crustacea*; but among the *Arachnida* tubes composed of basement-membrane, and containing epithelium, exist. Guanin also has been detected in them, so that there can be little doubt of their real nature. Among *Insects*, renal organs exist as long narrow tubes, and the presence of uric acid has been detected in several species. In the *Mollusca*, except in the lowest class, kidneys are distinctly observed, and are either two in number, or combined to form a single organ with an excretory duct. The spongy organs of the *Cephalopoda* have been proved to be true kidneys, and uric acid has been detected in them with the murexide test by E. Harless. Kidneys exist throughout the vertebrate classes, and are composed of tubular glands, provided with one or more efferent ducts, connected with which are often observed numerous appendages. The uriniferous tubule consists essentially of a tortuous tube of basement-membrane, lined with secreting epithelium, and dilated at its closed extremity, so as to embrace a tuft of highly tortuous capillary vessels.

The specific gravity of the healthy kidney is about 1·050, but is liable to vary somewhat, according to the quantity of fluid which exists in the organ at the time of examination.

The following is an analysis of the cortical portion of a healthy human kidney by Dr. Beale. The organ was taken from the body of a healthy man, thirty-one years of age, who was killed by falling from a second-floor window :—

		100 parts of Solid Matter
Water	76·450	
Solid matter	23·550	
Fatty matter, containing much cholesterine	·939	3·98
Extractive matter, soluble in water	5·840	24·79
Fixed alkaline salts	1·010	4·28
Earthy salts	·396	1·68
Albumen, vessels, etc.	15·365	65·24

Even in health, the proportion of water and solid matter varies greatly, which fully accounts for the varying statements of different observers with respect to the weight of the healthy kidney. In dis-

ase, the composition of the secreting structure of the kidney under-oes great alteration. The fat is very much increased in quantity n kidneys in a state of fatty degeneration. The relative proportion f the solids generally may be much diminished in quantity, which is emarkably the case in some specimens of enlarged kidney. The ncrease of size, in these instances, being accounted for by an un-sual quantity of water in the tissue of the organ; but in many cases, t is, no doubt, dependent upon deposition of new matter. In a very arge kidney, weighing half a pound, only 14·39 per cent. of solid natter was present, so that in this instance the increased weight of he organ was undoubtedly due to a larger proportion of water than ccurs in health, rather than to the deposition of any adventitious issue, or to an increase of the normal gland-textures.

Surface of the Kidney.—The kidney is immediately invested with firm fibrous coat, called the capsule, which is composed of con-lensed areolar tissue, and is continuous with the tissue constituting he matrix of the kidney, in the meshes of which the tubes ramify: ome small vessels also connect the capsule of the kidney with the roper gland-structure. At the hilum, the capsule is continuous with he external or fibrous coat of the pelvis of the kidney and the fibrous oat of the ureter. The vessels also receive an investment from it t this point.

If the surface of the kidney be carefully examined, it is seen to be mperfectly mapped out into a number of small polyhedral spaces or obules, in general appearance somewhat resembling the markings of he lobules of the liver. These markings are in part due to the rrangement of small branches of the veins which are spoken of by natomists as the stellate veins. Commencing at the surface of the idney, they penetrate the cortical part in a vertical direction, at early equal distances, and receive, in their course to the hilum, the lood from the venous plexuses surrounding the secreting tubes. In he spaces just described, may be seen the convolutions of some of he uriniferous tubes. No arteries reach the surface.

Ferrien supposed that the tubes formed little pyramids, each of which radiated from the *medullary* towards the *cortical* part of the idney, the base of each pyramid consisting of one of these spaces or obules. It appears, however, that although each pyramid contains nany tortuous tubes, with their capillaries, the convolutions of a ingle tube are by no means confined to one pyramidal space.

Besides the apparent divisions into lobules just referred to, the urface of the kidney bears the vestiges of several fissures, marking t out into lobes which may be seven or eight or more in number; hese lobes indicate the original condition of the kidney in intra-terine life when they were separated from each other, and formed listinct renules. In the embryos of mammalia generally, the same rrangement is observed; and it remains permanent in the cetacea. In the kidney of the otter, seal, ox, and some other animals, it is lso conspicuous. In the ox, the division into lobes extends only to he pyramids.

Parenchyma.—The parenchyma of the kidney consists of two dis-

tinct portions; the one *cortical*, about half an inch in thickness, forming the whole convex surface of the organ, of a dark red colour, and to the unaided eye of a granular appearance, and exhibiting numerous red spots (Malpighian bodies) abundantly scattered through it. The *medullary* portion is embraced in this; it is pale and smooth, arranged so as to form several pyramids, varying in number from eight to fifteen; their bases are placed towards the cortex, from which may be traced a number of nearly straight lines, which converge towards the summit of the pyramid to which they belong. In this part of the kidney there are no Malpighian tufts, and even to the unaided eye, it appears to be composed of a number of straight converging lines or tubes.

These pyramids or cones end by free summits which project on the hilum into the pelvis of the kidney, the mucous membrane lining this cavity being continuous at the summit of the cone (or mammilla) with the tubes. The mucous membrane of the pelvis, however, forms a sort of fossa, or saucer-shaped cavity, around each mammilla, or termination of the pyramid. These calyces receive the urine escaping from the open orifices of the tubes on the summit of the cones, and convey it toward the pelvis; they become enormously increased in dimensions if there be any obstruction to the passage of the urine from the ureter or bladder.

Matrix.—With reference to the presence of a fibro-cellular matrix in the kidney, which serves as a support for the vessels and tubes, there has been much difference of opinion. It was originally described by Goodsir, and has since been noticed by several observers.

The matrix appears to us to be composed of a firm transparent and granular substance, in which we have seen small granular cells; but have not been able to ascertain their precise nature. The fibrous appearance seen in thin sections we believe to be due rather to the crumpled state of the walls of the capillaries and uriniferous tubes, than to the existence of ordinary fibrous tissue in the matrix itself.

The intervals between the contiguous tubes and capillaries are greater in the pyramids than in the cortical portion of the organ, and consequently the matrix is more distinct in this situation; but even here it has only a faintly granular appearance, and we have been unable to see any distinct fibres.

It appears to us that this structure is of little physiological importance; it probably serves as a support for the tubes and capillary vessels.

As the tortuous tubes in the cortex pass in and out amongst the interspaces of this matrix, portions appear to be circumscribed, as it were, giving the idea upon a section of a number of small cysts,* an appearance which is often very marked in certain cases of disease, when the tubes are enlarged. In the kidneys of many rodents, especially in that of the mouse, this appearance exists in a very marked degree, in consequence of the highly developed condition of the matrix in these animals; but, in all the instances alluded to, the true

* On Diseases of the Kidneys, by George Johnson, M.D.

·e of this part, and often the continuity of the tube as it winds ɔut, can be demonstrated with ease. A thin section of the part of the kidney, made in any direction, displays these ıces containing sections of the tubes, between which may ȝ seen vessels which have been cut across.

iferous Tubes.—The uriniferous tubes, formerly termed tubes ini, in which the characteristic elements of the urine are se· consist of two distinct portions, as already alluded to; the highly *convoluted* part of the tubes, which is probably the t of true secretion, and the *straight* portion, which is directly ɔus with the former, and conducts the secretion towards the ; upon the mammilla, from which it passes into the pelvis of ıey. In the other direction, the convoluted portion of the ·minates in a dilated ty, which completely the vessels of the ıian tuft.*

Fig. 281.

From the human subject. This specimen exhibits the termination of a considerable arterial branch wholly in Malpighian tufts. *a.* Arterial branch, with its terminal twigs. At *α*, the injection has only party filled the tuft. At *β*, it has entirely filled it, and has also passed out along the efferent vessel *ef*, without any extravasation. At *γ* it has burst into the capsule, and escaped along the tube *t*, but has also filled the efferent vessel *ef*. At *δ* and *ε* it has extravasated, and passed along the tube. At *m* and *m* the injection, on escaping into the capsule, has not spread over the whole tuft. Magnified about 45 diameters.

ȝhall now consider, ıe minute structure Malpighian bodies; ŗ, that of the convo- ortion of the tube; ıstly, that of the portion.

ghian Bodies.—The ıian bodies are met all vertebrata. In ammalian kidney, here exists a division ·tical and medullary ı, they are only ı the former. In an specimen, they ap- the unaided eye, ıred points abund- ;attered throughout tex of the organ. ıry much in size in ; mammalia, and are arger towards the he cones. They are, most part, of a l, oval, or flask-like A small artery *affe- sel* may be seen to e tuft, and a minute radicle *efferent ves-* ȝmerge from it in

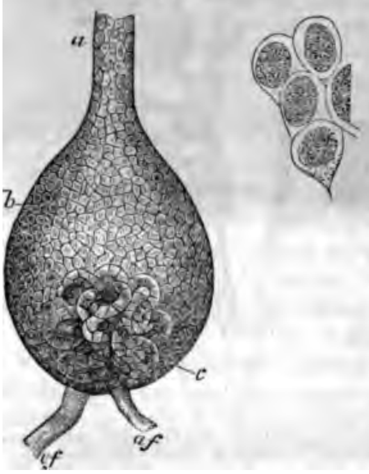
* Phil. Trans., 1842.

close proximity to the artery (fig. 231). The Malpighian body itself consists of a rounded bunch of capillaries derived from the afferent and terminating in the efferent vessel, the former dividing over the surface, the latter emerging from the interior. This vascular tuft lies within a clear and perfectly transparent capsule, lined at its lower part with epithelium. The epithelium, which is continued upwards from the uriniferous tube into its flask-like dilatation, cannot usually be traced for more than about one-third of the length of the capsule (fig. 3, p. 76); but in the proteus (fig. 232), the capsule is seen to be entirely lined with an exceedingly thin layer of delicate epithelium, the cells of which are of an oval, or polyhedral form, with a very large granular nucleus, and about the $\frac{1}{135}$ of an inch in diameter. The capsule itself consists of hyaloid membrane, which is directly continuous with the basement membrane of the convoluted portion of the tube. In fact, each uriniferous tubule terminates by a dilatation which embraces the vessels of the tuft, and is intimately united to them at the point where they enter and emerge.

The continuity of the tube with the Malpighian capsule has been proved in several ways. In specimens which have been carefully injected from the artery, not unfrequently it will be found that the coloured material escapes and extravasates from the vessels of the tuft into the cavity of the capsule, and thence runs down the tube (fig. 231).

In disease, it is not at all uncommon to find the capsule of the tuft, and the tube itself, injected with blood, in consequence of hemorrhage from the vessels of the tuft.

Fig. 232.



Malpighian tuft; kidney of the Proteus anguineus, showing vessels lying within the capsule, the inner surface of which is entirely covered with a single layer of tessellated epithelium. *a*. Uriniferous tube. *b*. Capsule. *c*. Tuft of vessels which were injected in the preparation from which this drawing was taken. *af*. Terminal twig of the artery. *ef*. Efferent vessel. Magnified about 50 diameters.—A small portion of the capsule, with its epithelial lining, is represented in the smaller figure, magnified 215 diameters.

The difficulty of injecting the capsule by forcing injection from the pelvis of the kidney, cannot reasonably be urged as an objection to this view, for all who have had any experience in injecting the minute ducts of glands, will agree that it is in very few instances, indeed, that the injection can be forced to the termination of the tube. The epithelium within it is apt to be forced towards its cæcal extremity, and by its accumulation renders such a result impossible; while, in the majority of cases, the force requisite to overcome the resistance to the passage of fluid, along a highly convoluted tube in the reverse direction to that which its contents naturally take, is more than sufficient to cause its rupture.

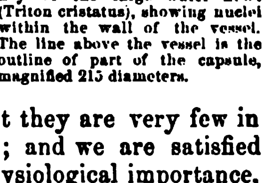
The kidney of the horse is very favourable for demonstrating these

points, and the double injection composed of acetate of lead and bichromate of potash will be found to furnish the most satisfactory results.

In the kidney of the frog, or of the newt, the continuity of the capsule with the basement membrane of the tube is exceedingly distinct and easy of demonstration. The tuft of vessels is seen lying naked within the capsule, uncovered either with epithelium or by any reflection of the basement membrane composing the capsule. In the frog, the neck of the tube close to and some way within the capsule is lined with ciliated epithelium, which continues in very active motion many hours after the death of the animal (*vide* fig. 3, p. 76.) In the newt, and in some snakes and other reptiles, the tube is completely lined with ciliated epithelium throughout; and by the activity of the motion, the epithelium can be traced for one-third of the way within the capsule. Ciliated epithelium has not yet been demonstrated in the kidneys of mammalia; but in one instance Gerlach has seen it in the kidney of the fowl. In various fishes and in many reptiles it is very frequently met with.

The statement of Gerlach and other observers, that the vessels of the Malpighian tuft are invested with epithelium, may be explained by the fact that small granular or nucleated cells may be frequently observed in connection with the vessels. After repeated and careful observation, we are convinced that these cells are situated either within the vessel itself or enclosed in its wall (fig. 233). In the tuft of batrachian reptiles, the white corpuscles of the blood often give the idea of being connected with the wall of the vessels, instead of lying in their interior. When the vessels are much shrunken, and their walls a little plaited, or corrugated, the appearance of cells lying upon the little capillary loops is produced when these loops are seen in profile. We have been able, in many instances, however, to demonstrate small oval or circular cells within the wall of the capillary vessel itself, and are inclined to look upon these as the nuclei of vessels. Here and there a granular cell may sometimes be detected on the surface, but they are very few in number and irregular in their arrangement; and we are satisfied that it cannot be regarded as a fact of any physiological importance, and that the vessels of the tuft are really bare within the capsule.

Fig. 233.

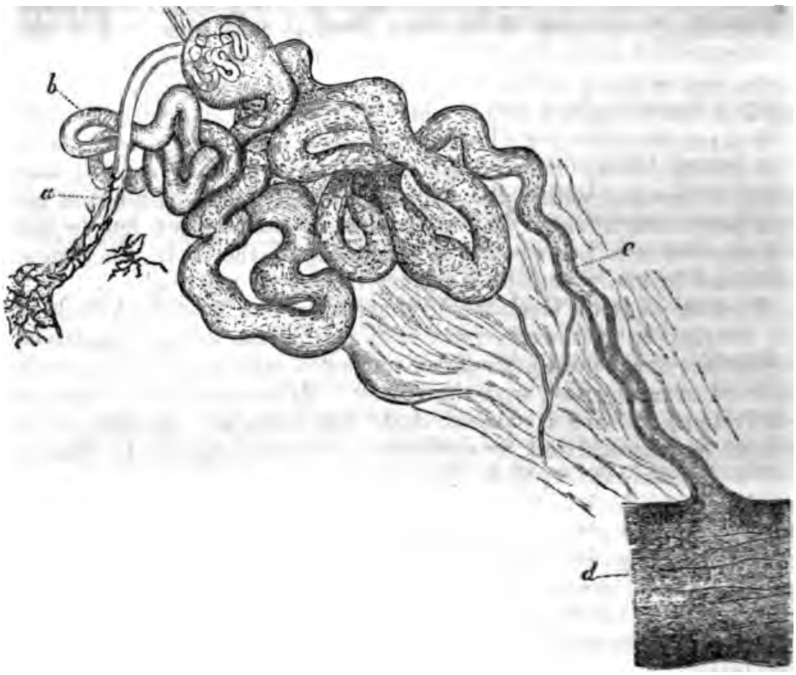


Small portion of a loop of capillary vessels of the tuft of the kidney of the large water newt (Triton cristatus), showing nuclei within the wall of the vessel. The line above the vessel is the outline of part of the capsule, magnified 215 diameters.

Convoluted Portion of the Tube.—From the capsule of the Malpighian tuft, we pass to the convoluted portion of the tube, which is directly continuous with it. This is composed of a delicate basement membrane, lined by epithelium. Externally, the basement membrane is in close contact and probably incorporated with the matrix of the organ; and it is in immediate relation with an abundant capillary plexus, which carries the blood after it has passed

through the vessels of the Malpighian body. It is from this blood that the elements characteristic of the urinary secretion are selected by the epithelium lining this part of the tube. The diameter of the tube is less immediately after leaving the tuft, than in the rest of its course further down (fig. 234). The epithelium in the convoluted

Fig. 234.



Entire uriniferous tube of the large black newt (Triton cristatus, female). *a.* Artery having [illegible] its walls numerous branched pigment cells. The commencement of the tube, and that part [illegible] tuft, are of less diameter than the central portion, which is the most active part of the [illegible]. Towards its termination in the upper part of the oviduct, *d*, the tube becomes straight and [illegible] narrowed, *c*. Magnified about 30 diameters, from a drawing of Dr. Beale's.

portion of the tube presents an excellent example of the spheroidal or glandular variety. It consists of polyhedral particles rather less than $\frac{1}{1000}$ of an inch in diameter, with a distinct nucleus, and containing numerous granules, and occupying as much as one-third or more of the total diameter of the tube.

The extreme diameter of the convoluted tube is about $\frac{1}{450}$ of an inch, while the diameter of the central canal is not more than from $\frac{1}{1000}$ to $\frac{1}{900}$ of an inch.

Straight Portion of the Tube.—The straight portion of the tubes of which the medullary cones or pyramids are composed form anastomoses, or if traced from the papilla towards the base of the pyramid, the large tubes near the apex may be said to divide dichotomously, so that the number of the individual tubes, which would

be seen in a transverse section, increases as we proceed from the apices of the pyramids towards their bases, while their diameter gradually diminishes. In the latter situation there may be many thousand tubes, while the number of openings upon the extremity of the mammilla are comparatively very few in number. The tubes at their orifices vary in diameter, from the $\frac{1}{300}$ to the $\frac{1}{200}$ of an inch, while towards the base of the pyramid they do not exceed $\frac{1}{500}$ of an inch. The aggregate capacity of the tubes at the base of a cone is enormously greater than that of the much smaller number of somewhat larger tubes at their orifices.

Fig. 285.

Transverse section of a pyramid of the human kidney, about a quarter of an inch from the papilla. *a.* Section of largest tubes. *b.* Section of smaller tubes, at a point previous to their opening into a larger one. The thin delicate epithelium approaching to the squamous variety, is seen lining this straight portion of the uriniferous tubes. *c.* Small vessels which ramify between the tubes in the transparent granular matrix. *d.* Magnified about 120 diameters.

The epithelium in this situation differs in character from that in the convoluted portion of the tubes; the cells are smaller, more transparent, and approach more nearly to the scaly or tessellated variety. They seem rather to serve as a protective layer than to share in the secreting function. The cells here are usually very thin, approaching to squamous epithelium in character; and although the total diameter of the tube is less than that of the convoluted portion, the diameter of the central canal is greater.

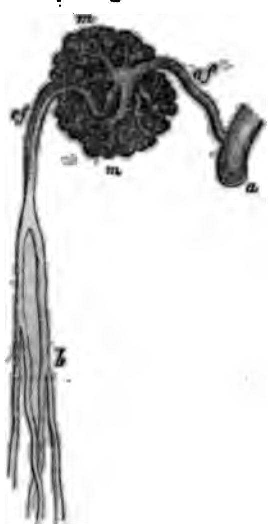
Fig. 286.

Malpighian tuft from the horse. The injection has penetrated only to the capillaries. *a.* The artery. *af.* One of its terminal twigs (or the afferent vessel). *d.* The dilatation and mode of breaking up of the terminal twig after entering the capsule. The division of the tuft into lobes, *l*, *l*, *l*, is well seen. *i*, *i*. Intervals between the lobes. Magnified about 80 diameters.

Vessels of the Kidney.—The renal arteries divide into four or five branches, which enter the kidney at the hilum between the vein and the ureter. These vessels are surrounded with a quantity of fat. They pass between the papillæ to the bases of the cones over which they spread. From these arteries smaller branches are given off, which ascend in the cortical substance nearly to the surface, and, in so doing, give off, on all sides, a number of small terminal twigs, the afferent vessels of the Malpighian bodies. Arrived within the capsule, the small afferent vessel at once divides into four or five branches, each of which again divides dichotomously. The small capillary vessels form loops, which project towards the opening of the uriniferous tube. The blood is received from these vessels, which lie towards the outside of the tuft, by branches of the efferent vessel which converge towards the more central part of

the tuft to form one trunk, which leaves the Malpighian body, and soon breaks up into a plexus of capillary vessels, in the meshes of which the tubes lie. The terminal arterial twigs with their appended tufts, when injected with vermilion, have been compared not inaptly to a bunch of currants.

Fig. 237.

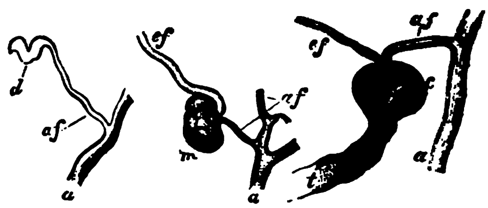


Malpighian tuft, from near the base of one of the medullary cones, injected without extravasation, and showing the efferent vein branching like an artery as it runs into the medullary cone. *a.* Arterial branch. *af.* The afferent vessel. *m, m.* Malpighian tuft. *ef.* The efferent vessel. *b.* Its branches entering the medullary cone. Magnified about 70 diameters.

The size and complexity of the Malpighian bodies differ much in different animals, according to the activity of the function they are called upon to discharge. The vessels present fewer convolutions, the tufts are smaller, and their arrangement much simpler, in those animals in which the urine is almost of a solid consistence. Compare the complicated arrangement in the horse and other mammalia in figs. 236 and 237, with the few and simple convolutions in birds, fig. 238.

By reference to the table on next page, it will be seen that the diameter of the tuft in the parrot and in the boa, is less than in any other instance recorded; and in these animals, as is well known, the urine is almost solid. It is especially worthy of remark, that the uriniferous tubes do not exhibit a corresponding difference in dimensions.

Fig. 238.



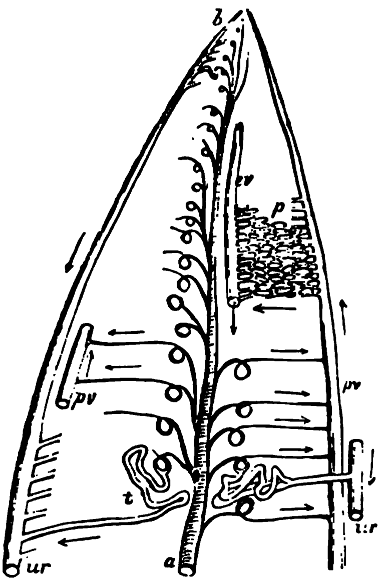
From the parrot; injected by the artery. *a, a, a.* Terminal branches of the artery. *af, af, af.* Terminal twigs of the artery. *d.* Dilatation of the terminal twig on entering the Malpighian capsule. *m.* This dilatation more completely filled, showing its convoluted form; and, *ef, ef*, the efferent vessel. *c.* The Malpighian capsule filled by extravasation from the contained vessel, and the tube *t* likewise filled. Magnified about 80 diameters.

Table of the Diameter of Malpighian Bodies, and of the Tubes emerging from them, in Fractions of an English Inch.

	Diameter of Malpighian bodies.			Diameter of Tubes.
	Maximum.	Mean.	Minimum.	
Man	$\frac{1}{80}$	$\frac{1}{104}$	$\frac{1}{144}$	$\frac{1}{480}$
Dog	$\frac{1}{120}$	$\frac{1}{133}$	$\frac{1}{158}$	$\frac{1}{500}$
Rat	$\frac{1}{208}$	$\frac{1}{180}$	$\frac{1}{150}$	$\frac{1}{416}$
Horse	$\frac{1}{55}$	$\frac{1}{70}$	$\frac{1}{96}$	$\frac{1}{416}$
Parrot	—	$\frac{1}{430}$	—	$\frac{1}{500}$ to $\frac{1}{700}$
Tortoise	—	$\frac{1}{240}$	—	$\frac{1}{480}$
Boa	$\frac{1}{250}$	$\frac{1}{400}$	$\frac{1}{430}$	$\frac{1}{540}$

The small efferent vessel from the Malpighian tuft passes at once into the plexus round the tubes, and, as it lies between the capillary plexus of the tuft, on the one hand, and that surrounding the tubes upon the other, it bears the same relation to these two capillary systems as the portal vein bears to those of the intestinal canal and the liver; hence these efferent vessels may be regarded as analogous to a portal system of vessels. This view is further strengthened by an examination of the arrangement of the vessels in the kidney of the boa constrictor, figs. 239, 240. In this animal, the blood, after passing through the capillaries of the Malpighian tuft, enters the efferent vessel, which conducts it into the branch of a portal vein ramifying upon the surface of the lobule. From the portal vein, it passes into a system of venous capillaries surrounding the tubes, from which it is at last carried into the emulgent veins, which, with the artery, lie in the central part of the lobule.

Fig. 239.



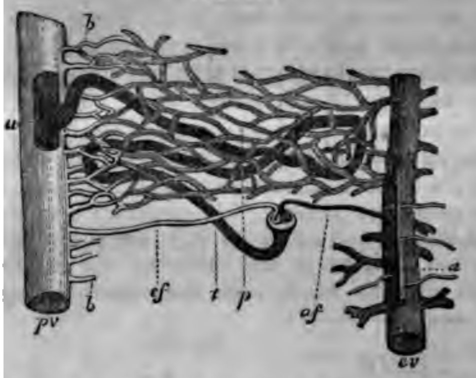
Plan of the arrangement of the elements of a lobe of the kidney in the boa constrictor. The references are the same as in Fig. 240.

"The comparison between the hepatic and the renal portal circulation may be thus drawn in more general terms. The portal system of the liver has a double source, one extraneous, the other in the organ itself; so the portal system of the kidney, in the lower tribes, has a twofold origin, one extraneous, the other in the organ itself. In both cases, the extraneous source is the principal one, and the artery furnishing the internal source is very small. But in the kidney of the higher tribes, the

portal system has only one internal source, and the artery supplying it is proportionably large."*

Of the Secretion of Urine.—Having passed in review the anatomical arrangement of the different structures composing the kidney, we shall now proceed to consider briefly the functions which the several parts perform. First, with regard to the Malpighian tufts; we have already seen that in animals, in which the urinary excrement is passed in an almost solid form, the tufts are small and simple compared with those in the kidneys of animals which pass the urinary constituents in solution in a large quantity of water. There can be little doubt that the special function of the vessels of the tuft is, to furnish the fluid portion of the urine, while the solid matter, composed of various organic constituents and inorganic salts, is separated by the aid of the glandular epithelium which lines the convoluted portion of the tubes. "It would, indeed, be difficult to conceive a disposition of parts more calculated to favour the escape of water from the blood than that of the Malpighian body. A large artery breaks up in a very direct manner into a number of minute branches, each of which suddenly opens into an assemblage of vessels of far greater aggregate capacity than itself, and from which there is but one narrow exit. Hence must arise a very abrupt retardation in the velocity of the current of blood. The vessels in which this delay occurs are uncovered by any structure. They lie bare in a cell from which there is but one outlet."† The arrangement of the convoluted portion of the tubes is very similar to that of other

Fig. 240.



Part of Fig. 239 shaded, showing the arrangement of the vessels and uriniferous tubes in the kidney of the boa, and in animals furnished with a portal vein from an extraneous source. *a*. Artery. *af*. Terminal twig going to Malpighian body. *ef*. Efferent vessel of the Malpighian body emptying itself into a branch of the portal vein, *pv*, on the surface of the lobe. *b*, *b*. Ultimate branches of the portal vein entering the capillary plexus, *p*, surrounding the uriniferous tube, *t*. *u*. Branch of the ureter on the surface of the lobe. *ev*. Emulgent vein within the lobe, receiving the blood from the plexus surrounding the uriniferous tubes. Supposed to be magnified about 40 diameters.

Fig. 241.

Plan of the renal circulation in man and mammalia. *a*. Terminal branch of the artery, giving the terminal twig, 1, to the Malpighian tuft. *m*, from which emerges the efferent or portal vessel, 2. Other efferent vessels, 2, are seen entering the plexus of capillaries surrounding the uriniferous tube, *t*. From this plexus the emulgent vein (*v*) springs.

* Phil. Trans., 1842.

† Phil. Trans., 1842.

secreting tubular gland-structures. We have a delicate basement membrane in contact with vessels upon one surface and having secreting epithelium upon the other. The capillary network surrounding the uriniferous tubes is the counterpart of that investing the tubes of the testes; and the epithelium is allied in structure to the best marked examples of glandular epithelium, and there can be no doubt that the function of these cells is such as we have described. There is no reason for supposing that the cells of epithelium undergo rapid decay and renovation; it appears more probable that they are not being constantly shed, either in an entire or disintegrated state, but that they have the power of selecting certain materials from the blood, and afterwards giving them up without their destruction. In the straight portion of the tubes the epithelium becomes thinner, and approaches more nearly to the pavement variety. It probably serves principally as a protective covering, and takes no part whatever in the secretion of the urine.

URINE.

Healthy urine is a clear, limpid fluid, of a pale straw colour, emitting a peculiar and characteristic odour while warm, and exciting a saline and somewhat bitter taste. As the solid constituents of this fluid are entirely excrementitious, and in great part derived from the disintegration of the tissues concerned in the chemical changes connected with animal life, we should be led to expect that any alteration in the activity of these functions would lead to a corresponding variation in the characters of the urine. Even in a state of health the qualities of the urine vary much; and it has been found that active exercise exerts a considerable influence upon the quantity of some of the most important constituents of this fluid. Nitrogenous matter, taken in greater quantity than is required for the wants of the system, will be eliminated by the kidneys in the form of urea, and the composition of the urine will therefore be influenced by the character, as well as by the quantity of the food.* If an unusual quantity of water be taken into the stomach, a great proportion will rapidly be eliminated by the kidneys, and the urine will be found to be very dilute, and of low specific gravity. Again, as the action of the kidneys is materially affected by the activity with which the functions of the skin are discharged, the condition of this great secreting surface has much to do with the quantity and quality of the urinary secretion. Changes of temperature, for the same reason, will cause the urine to vary in quantity. In hot weather, when the functions of the skin are increased, and a large amount of water is in this way removed from the system, in order to compensate for the effects of the increased external heat, the urinary secretion is much diminished in quantity, and becomes more concentrated, while, in cold weather, when this cooling effect of evaporation is not required, we find the amount of urine much increased, and, therefore, diminished in density. A dry, or humid state of the atmosphere, in consequence of affecting the rapidity of cutaneous transpiration, will exert a certain amount of influence on the quantity of water. It does not appear, however, that the quantity of the solid constituents excreted in a given time is much altered by these circumstances. The state of the nervous system will often be found to have a decided influence in modifying the characters of this secretion; and various mental emotions, such as sudden joy, or fright, or anxiety, will cause the secretion of urine having a much larger proportion of water than usual.

All these circumstances, and many others of less importance, have been found to affect the characters of healthy urine; and, on this account, considerable difficulty has been felt in attempting to define the precise characters of the secretion in health. Again, the composition of the urine differs at different periods of life, but in a much

* The frequency with which we meet with an excess of urea in the urine of our countrymen is probably dependent in some measure upon the highly nitrogenous nature of our food. On the continent of Europe this is so rare, that some foreign observers appear hardly to credit the statements with reference to the frequent presence of excess of urea.

...gree in different individuals at the same period. The urine of men, in the ..., contains more solid matter, and less water, than that of old men, women,

... *Urine.*—The quantity of urine discharged in the course of twenty-four ... ate of health, varies very much, but it may be said to amount to about 30 ... ces. The density varies from 1·010 to 1·020 or 1·025 and the quantity of ... er from 4 or 5 to 8 per cent. The amount of solid matter eliminated from the kidneys of a healthy man who lives well may be roughly stated to be about 1000 grains in twenty-four hours.

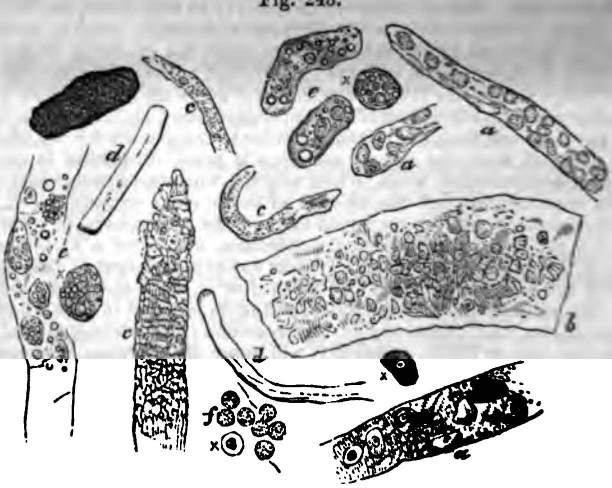
Fig. 242.

a. Vari... it of lithate ... ierules with ... of lime. c. ... f.

Reaction.—Healthy urine exhibits an acid reaction; but the intensity of the reaction varies at certain periods of the days. Dr. Bence Jones, who has lately investigated this subject, found that the urine was most acid immediately before meals, and the intensity of the acidity diminishes until five or six hours after the meal. This condition, occurring in the urine secreted soon after digestion, depends upon the quantity of alkali set free in the blood in consequence of the decomposition of certain salts which furnish the acid entering ... of the gastric juice.

The reaction of healthy ... ttributed to the presence of free lactic acid, and also to acetic acid; but the investigations of Liebig have rendered it probable that it depends, not upon the existence of free or uncombined acid, but upon the presence of certain salts which exhibit a decidedly acid reaction, although there is no free or uncombined acid. Such salts are presented to us in the phosphates, which have the property of being very readily changed from the alkaline to the acid, or super-salt.

Fig. 243.



Casts of the uriniferous tubes. *a.* Casts with epithelium, at *x* a free cell of epithelium. *b.* Very large cast containing epithelium. *c.* Small granular casts. *d.* Small waxy cast. *e.* Casts containing fat cells and free oil, at *x* cell filled with fat globules. *f.* Pus globules, at *x* once acted upon by acetic acid.

After standing for some hours, healthy urine deposits a slight precipitate, forming a light flocculent cloud, consisting of vesical mucus, and a little epithelial debris. This deposit is much more abundant in the urine of women, in consequence of the admixture of a considerable quantity of vaginal epithelium. Not unfrequently, epithelium from the urethra, or bladder, will be found in this deposit, and spermatozoa are occasionally met with. In disease, the deposit may consist of pus, or blood-corpuscles, and fibrinous moulds of the uriniferous tubes,* entangling cells of renal epithelium, which may contain many oil globules, and crystals of oxalate of lime, pus, or blood globules, are sometimes found. In such cases, the urine will also contain albumen. Among the deposits most frequently observed, may be mentioned the amorphous deposit of lithate of soda, crystals of lithic acid, of oxalate of lime, of triple or ammoniaco-magnesian phosphate, and occasionally crystals of cystine.

Fig. 244.

a Crystals of triple phosphate. *c*. Stellate variety. *b*. Granules of phosphate of lime. *d*. Crystals of cystine.

Composition of Healthy Urine.—The urine is a highly complex fluid, and contains substances having very different properties. Its constituents are composed partly of organic, and partly of inorganic compounds which are held in solution in the aqueous portion of the secretion. A small quantity of carbonic acid gas is likewise often found held in solution. The chief organic constituents of healthy urine are the following: *urea*, *uric* or *lithic acid*, and certain *extractive matters*, with small quantities of *creatine*, *creatinine*, *hippuric* and *lactic acids*, and *ammoniacal salts*. The inorganic constituents consist of certain salts which enter into the composition of the food, but which are not required for the wants of the system, and salts which, having performed certain offices by their passage through the tissues, are no longer required, and certain other saline compounds, which, like many of the organic constituents, are formed by oxidation in the processes concerned in nutrition. The inorganic salts are composed of *chlorides*, *sulphates*, and *phosphates*, with traces of *silica*, and the bases entering into the composition of these salts are, *potash*, *soda*, *lime*, and *magnesia*. It is exceedingly difficult to ascertain the precise composition of the salts as they were originally held in solution in the urine; for, in the processes of evaporation, and subsequent incineration, certain decompositions take place, which entirely alter their nature. The quantities in which these substances occur, vary in different specimens of urine, and the published analyses of the secretion in a healthy state, will be found to differ considerably from each other. This difference arises chiefly from the variation in the proportion of water; for, by calculating the relation existing between the quantities of the several solid constituents, it will be found to be nearly the same in all.

The following is an analysis of healthy human urine, by Dr. Miller. The percentage composition of the solid matter is shown in a separate column. Specific gravity, 1.020.

			In 100 of Solid matter.
Water		956·80	
Solid matter		42·98	
Organic matters 29·822	Urea	14·23	33·10
	Uric acid	·37	·86
	Alcohol extractive	12·53	29·15
	Water extractive	1·60	3·72
	Vesical mucus	·17	·39
	Muriate of ammonia	·91	2·11
Fixed Salts 13·158	Chloride of Sodium	7·22	16·79
	Phosphoric acid	2·12	4·93
	Sulphuric acid	1·70	3·95
	Lime	·21	·48
	Magnesia	·12	·27
	Potash	1·93	4·40
	Soda	·05	·11
		999·96	

* Diseases of the Kidney, by George Johnson, M. D.

Urea ($C_2H_4N_2O_2$) constitutes nearly half of the solid matter of healthy urine, and the secretion itself contains from 2·5 to 3·2 per cent. of this substance. The quantity, however, is much increased by exercise, or by a purely animal diet. According to Lehmann, when a highly nitrogenous diet is taken, a quantity of urea equal to nearly five-sixths of the nitrogenous matter introduced is eliminated by the kidneys. A considerable quantity of urea, however, is formed when no food whatever is taken, or when a non-nitrogenous diet is adhered to for a considerable period, which clearly shows that a large proportion of urea is derived from the disintegration of the tissues, by the process of secondary assimilation. It is often detected in abnormal quantity in the urine of patients suffering from rheumatism, and certain febrile complaints, and, in various diseases, it may sometimes be obtained from this fluid in very large quantities. This condition is very commonly associated with diseases of the kidneys, and leads to the development of coma, which is often fatal. Urea has been detected in the blood of patients suffering from cholera, and once by Dr. Garrod, in that of a gouty patient. In the serous fluids poured out in various parts of the body, in cases of kidney disease, as well as in several of the secretions, such as the saliva, &c., it has been found in large quantity. Dr. Owen Rees has met with it in milk, and the same observer, and Wöhler, have found it in the liquor amnii, an observation, however, which others have failed to confirm. It has been detected in the aqueous and vitreous humours of the eye.

There can be little doubt that urea is formed in the blood by the action of oxygen upon lithic acid, creatine, and, possibly, upon some of the matters comprehended under the indefinite term of extractive matter. In a state of health it is so rapidly separated from the circulating fluid, in its passage through the kidneys, that its presence is not easily recognized; but, in animals in which these organs have been extirpated, it accumulates in sufficient quantity in the blood to be detected with facility. Urea cannot be extracted from the muscles, although it is probable that the greater quantity excreted is formed from the effete materials produced by muscular action, since the quantity of urea is so much increased by exercise, and is also produced, although only non-nitrogenous food be taken. At the same time, it is almost certain, that if an amount of nitrogenous food greater than is required by the wants of the system, be taken, the excess becomes converted into urea, and is eliminated from the system by the kidneys.*

Uric or Lithic Acid ($C_{10}H_4N_4O_6$) is always present in healthy urine, and exists in the proportion of about one part in a thousand. It may very readily be obtained by the addition of a few drops of hydrochloric acid to a portion of the urine placed in a conical glass vessel. After the lapse of a few hours, the uric acid is found deposited in the form of small crystalline grains, adhering to the sides or collected at the bottom of the glass. Uric acid prepared in this manner is always highly coloured, which arises from the circumstance of its having a great affinity for the colouring matter of the urine.

Uric acid exists in healthy urine in combination with soda, and perhaps also with ammonia and lime; as these salts are only present in small quantity they are held in solution, but in the urine of patients suffering from fever, they often form an abundant deposit, which, in this country, is generally known as lithate of ammonia, although Lehmann, Becquerel, and Heintz, all agree that it is composed principally of lithate of soda.

In the urine of the carnivora, uric acid is present in small quantity, but, as a general rule, it is absent from the urine of the herbivora; and, curiously enough, also, it cannot be detected in the urine of the omnivorous pig. The excrement of birds, and that of serpents and other reptiles, and of many insects, contains a large quantity

* It has lately been advanced by Dr. Frerichs, that in cases in which the urea is prevented from being eliminated from the blood, either by the extirpation of the kidneys (as in his experiments upon animals), or in cases in which the functions of these organs have been impaired by disease (as in certain forms of Bright's kidney), this substance is resolved, whilst in the circulating blood, into carbonate of ammonia; the presence of which, according to this observer, gives rise to the coma which so frequently carries off patients in an advanced stage of renal disease. We should, however, state, that this view has not yet received confirmation from the experiments of others. That a considerable quantity of urea may be present in the blood without giving rise to any serious symptoms, we can affirm from actual experiment; but at the same time, we consider that there is sufficient evidence to prove that the coma, in many cases of kidney disease, is dependent upon the presence of urea. We have tested the breath of a few patients suffering from this form of coma, in King's College Hospital, and have also examined the blood, but have failed to demonstrate the presence of carbonate of ammonia.

of alkaline urates. Guano, as is well known, is chiefly composed of lithate of ammonia.

After profuse perspiration, the quantity of uric acid has been found to be diminished in the urine; but a purely animal diet exerts but little influence upon the quantity of this substance excreted by the kidneys. It is much increased, however, in all febrile conditions of the system, and after imperfect digestion of food. In cases where the respiratory function is impaired, the amount of uric acid has been found to be abnormally increased; and insufficient exercise will produce a similar effect.

Uric acid has been detected in the blood of healthy men by Garrod, and in considerably increased proportion in the blood of gouty patients. It has also been detected in the perspiration, and the deposits formed about the joints of gouty persons are largely composed of it.

According to Wohler and Frerichs, the introduction of lithic acid into the blood is followed by an increased secretion of urea and oxalate of lime in the urine, a point of considerable interest when we know that, by the influence of peroxide of lead, a similar decomposition of the lithic acid may be induced artificially.

When all these circumstances are considered, more especially that, in certain instances in which the respiratory changes are not carried on with the activity consistent with perfect health, a greatly increased quantity of lithic acid is eliminated by the kidneys, there appears ample evidence to show that lithic acid is one of the purely excrementitious substances derived from the disintegration of the tissues, and formed by the action of oxygen upon effete material. By a process of further oxidation, the lithic acid itself becomes converted into urea as we just now mentioned.

Hippuric Acid ($C_{18}\,H_8\,NO_5$, HO), according to Liebig, exists in small quantity in healthy human urine, but it is obtained in considerable quantity from the urine of horses, cows, and other herbivorous animals. It is quite inodoreus, has a rather bitter taste, is slightly soluble in cold, but very soluble in hot water and alcohol, characters in which it differs from uric acid. It is easily prepared from the urine of cows by precipitation by hydrochloric acid, and subsequent purification. It is, however, absolutely necessary that the urine should be perfectly fresh, otherwise the hippuric acid will be found to have been entirely converted into benzoic acid, a change which may also be induced in the pure acid by the action of heat and mineral acids. It has been stated by Mr. Ure, that if benzoic acid be taken, it is eliminated from the system as hippuric acid.

Hippuric acid has been found in the urine of many herbivorous animals, and by Lehmann in that of the tortoise (*Testudo Græca*) and many herbivorous insects. It is not present in the urine of the carnivora. In cases of diabetes, it is stated by the same observer to be never absent from the urine; and in health, may usually be detected if the diet be purely of a vegetable character. This acid, like uric acid, must be looked upon as an excrementitious substance, and plays no other part in the system.

Creatine ($C_8\,H_9\,N_3\,O_4$) occurs in very small quantity in the urine. It is a colourless crystalline body, with a strong pungent taste, soluble in cold, and very soluble in boiling water; it is almost insoluble in alcohol. Boiled with baryta water, it becomes changed into urea and sarcosine; and it is probable that a somewhat similar decomposition ensues within the organism, and that, of the quantity of creatine formed in the muscular fibre, a large proportion is eliminated from the system in the form of urea, and partly, perhaps, as carbonic acid and ammonia.

Creatine was obtained, in the beautiful investigation of Liebig, from the flesh of various animals; but the proportion in which it exists is so small that it can only be extracted with great care, and by operating upon large quantities. It occurs most abundantly in the flesh of fowls, and in the heart of the ox.

Creatinine ($C_8\,H_7\,N_3\,O_2$) is also met with in the urine, and its presence in this fluid was discovered by Liebig, to whom we are indebted for all that is known in reference to this body. Creatinine crystallizes in colourless crystals. It possesses a hot, burning taste, compared to caustic ammonia. It is soluble in water, and, unlike creatine, is freely dissolved by spirit. It is found, with the last mentioned body, in the juice of muscular fibre. Creatinine may be formed by the action of hydrochloric acid upon creatine, a change which renders it probable that it is also formed from the last named body in the organism. In urine, creatinine exists in larger quantity than creatine; while in muscular fibre the latter is found to exceed the former in amount.

Extractive Matters.—Under this very unsatisfactory term are included certain substances met with in the urine, blood, and other animal fluids which are not easily isolated, whose properties are with great difficulty determined, which do not crystallize, are not volatile without decomposition, and cannot be obtained in a pure form. Of

late years, however, several substances have been separated from the extractive matters which were formerly included under that term. Of these, albuminate of soda, creatine, and creatinine may be referred to as examples. These extractive matters no doubt play a most important part in vital chemistry, and probably represent a stage intermediate between the nutritive pabulum and the tissues formed from it, or between the latter in process of disintegration and the compounds we have been considering, such as urea, lithic acid, etc., but in the present state of our knowledge, little beyond mere speculation can be advanced.

Our friend, Dr. G. O. Rees, found that, in cases of albuminuria, connected with kidney disease, large quantities of the extractive matters of the blood passed off in the urine as well as albumen. The test which Dr. Rees employed for detecting the presence of the blood extraction was the tincture of galls.*

Ammoniacal Salts.—Ammonia exists in very small quantity, if, indeed, it be present in healthy urine, but in disease a considerable proportion may occur. It has been found as hydrochlorate, lactate, biphosphate, ammonio-magnesian or triple phosphate, and in the form of phosphate of ammonia and soda. Its presence usually depends upon the decomposition of some of the nitrogenous constituents of the urine, as previously indicated.

Fixed Salts.—By the careful incineration of urine, we obtain the fixed salts, and we find that, of the saline residue, part is soluble and part insoluble in water, the latter having been previously held in solution in the urine by some material which has been destroyed by a red heat. Although the presence of certain acids and certain bases in the ash is readily demonstrated, the precise manner in which these were originally united together is not so easily ascertained.

The most important saline constituents of normal urine are chlorides, sulphates, and phosphates; and the following bases are present—potash, soda, lime, magnesia, with traces of silica and peroxide of iron.

Chlorides.—The chlorine exists in combination with sodium, in the form of common salt, and perhaps also occasionally as hydrochlorate of ammonia. Almost the whole of the chloride of sodium is probably derived from the food; although, from recent investigations, it appears probable that this substance plays an important part in the development of tissues, and also in certain morbid changes. In growing tissues, it is always abundant, and in the fluid on the surface of healing ulcers it exists in large quantity.†

Sulphates.—The sulphuric acid exists in combination with potash, and perhaps also with soda. The sulphates are highly important saline constituents, and their proportion is much influenced by the activity of the vital functions, and also by an animal diet. After exercise, the amount of the sulphates, as well as that of the urea, undergoes an increase; and it has been found that in *Chorea* (a disease characterized by inordinate action of the muscular system) a large quantity of these salts are excreted in the urine.‡ The sulphuric acid is, doubtless, in great measure produced by the oxidation of the sulphur contained in the proteine compounds. Unlike the chlorides, the sulphates are not present, or are only met with in very small quantities, in the fluids of the body generally, with the exception of the urine, a circumstance which points to the importance of the former in the organism, while it clearly shows that the latter are not required in the nutritive changes, and are, therefore, only to be found in the excrements.

Sulphuretted Hydrogen is from time to time detected in urine. Dr. Beale met with it frequently in the urine of insane patients. Sulphur is no doubt eliminated in considerable quantity in the urine in certain cases. Cystine contains as much as 26 per cent. of this substance.

Phosphates.—Phosphoric acid is found in combination with soda, lime, and magnesia; the salts thus constituted have been spoken of as alkaline or earthy phosphates, the former term being confined to the combination of phosphoric acid with soda, and the latter to the phosphates of lime and magnesia, which are precipitated from healthy urine by the simple addition of excess of ammonia.

The large amount of phosphates present in urine is chiefly derived from the food, but part results from the oxidation of the phosphorus which is contained in the tissues; the particular tissue concerned in the formation of this phosphoric acid being the nervous, which, it is well known, contains a large proportion of phosphorus. Dr.

* Lettsomian Lectures. London Medical Gazette, vol. xlviii., 1851.

† "On the Diminution of the Chlorides in the Urine in Cases of Pneumonia," by Lionel Beale. Med.-Chir. Trans., vol. xxx.

‡ Dr. Bence Jones. Med.-Chir. Trans.

Bence Jones found an increase in the quantity of the alkaline phosphates in the urine of some cases of inflammation of the brain, and a diminution in quantity in cases of delirium tremens when no food was taken; but in the latter case the diminution is, probably, too slight to be recognized. This circumstance would account for the result of several experiments we have ourselves made upon this point, in which we have found no diminution in the quantity of phosphates.

To sum up, the kidneys appear to be special organs for the removal of effete material produced in the vital processes from the system, and they serve as channels for the elimination of water and certain saline matter, as well as excess of nitrogenous material which is not required for the maintenance of the tissues. The chief constituents of the urine consist of compounds resulting from the action of oxygen upon the albuminous or allied substances; and in urea and uric acid we have probably examples of the highest state of oxidation which the chemical elements of the tissues are capable of undergoing, and urea may be looked upon as the last of a series of compounds resulting from the successive action of oxygen upon those bodies which stand above it on this scale. The fixed salts which occur in urine also exist in a highly oxidized state. There can be little doubt, that the highly complex substances entering into the formation of the tissues, by chemical action taking place in the organism, become resolved into bodies of a more simple composition, until they are eliminated in the form of urea or some allied compound, the elements of which are so loosely combined, that by external circumstances alone new substances are formed of a still simpler composition, such as carbonic acid and ammonia. In these, however, the elements are united with such force, that it is only by most powerful chemical action, or by the still more powerful influence of the vital properties of plants, that they can be separated from each other, and again applied to the building up of those highly complicated substances of which the tissues of animals consist, and which, by their vital processes, are again reduced in complexity as before.

The more actively the vital phenomena are performed, or, in other words, the greater the rapidity with which the disintegration and repair of the tissues take place, the larger is the quantity of urea excreted from the system. With this increase of the urea, there is certainly a corresponding increase of the sulphates, and perhaps also of the phosphates. If, however, the activity of these changes be interfered with, as from impairment of the respiratory apparatus, or from other causes, as might be expected, we find an increase of that constituent which stands next above urea in the descending series of compounds resulting from oxidation, namely, *lithic acid.* This finds its way out of the system in the form of lithate of soda, forming the amorphous sediment generally known as lithate of ammonia, but which really consists almost entirely of lithate of soda. Under similar circumstances, we often meet with a deposit of *oxalate of lime.* The urine of the active carnivora contains, like that of man, a large quantity of *urea;* on the other hand, the urine of serpents and many other reptiles consists almost entirely of *uric acid* in combination with ammonia. The urine of birds much resembles in character that of serpents, which appears somewhat to be opposed to the doctrine we have been endeavouring to inculcate, as the vital changes are carried on with greater activity in this than in any other class of animals; but, on the other hand, it may be argued, that the demand for oxygen is so great in birds, and their vital functions so actively carried on, that the extensive respiratory apparatus necessary for the supply of sufficient oxygen to convert all the uric acid into urea would be incompatible with the lightness of their bodies, which is so necessary for flight; while the removal of the urinary constituents in a state of solution involves the necessity of a bladder, or receptacle, in which it can collect, and which would still further add to the weight. We find in the minute anatomy of the bird's lung a beautiful arrangement by means of which not the smallest space where blood can be exposed to the action of air is lost. (*Vide* p. 715.)

Pelvis of Kidney and Ureters.—The mucous membrane lining the pelvis of the kidney is continuous with that of the renal tubes at the point where they open upon the papillæ, in which situation it is exceedingly thin, and it is difficult to distinguish its epithelium. The epithelium of the pelvis of the kidney generally is polygonal in form, and constitutes a tolerably thick layer. The deeper cells are small and rounded. Many cells approaching to the columnar form may also be observed; and these increase in number towards the ureter, which tube is lined with this variety of epithelium.

The ureters have muscular coat composed of two layers, an internal layer of circular, and an external one of longitudinal fibres. These are prolonged upwards into the pelvis of the kidney, and cease at the calyces. The muscular coat is composed entirely of unstriped muscular fibre cells, the nature of which will be particularly described when we come to speak of the uterus, and it is invested with an external coat composed of fibrous tissue.

The ureters reach the base of the bladder, run obliquely through its coats for the distance of nearly an inch, and open into this viscus by two narrow slit-like openings about an inch and a half behind the prostate on its inferior surface, and separated from each other by the distance of nearly two inches. The openings readily permit the urine to pass into the bladder; but, by their arrangement, completely prevent its reflux into the ureter; the reflection of mucous membrane at their mouth serves the office of a valve.

We have already referred to the contraction of the ureters in p. 765 of the present volume.

Bladder.—The urinary bladder is the large receptacle into which the urine is poured and in which it accumulates as it escapes from the ureters. Its size varies very greatly: it may be distended to such a degree as to contain nine, or even twelve pints of urine, in which case its walls of course become exceedingly thin, or it may be contracted so much as to leave scarcely any visible cavity in its interior. Its contracted muscular walls may be found half an inch or more in thickness, a condition very often met with in cases of cholera.

The internal surface of the bladder has a reticulated appearance, owing to the arrangement of the muscular fasciculi. The mucous membrane is sometimes forced through the small spaces between the fibres, and thus a number of sacculi are produced, a condition termed *sacculated bladder.*

At the lower part of the bladder is a perfectly smooth and pale surface, of the form of an equilateral triangle, the apex of which points towards the prostate. The ureters open one at each of the posterior angles; and between them there is a prominent line caused by the mucous membrane being somewhat raised in this situation. This triangular portion of the floor of the bladder is called the *trigone* (triangle), and the mucous membrane is attached more firmly than in other parts to the muscular coat beneath, whence its smooth character. The bladder is only partially covered with peritoneum. It is connected in the male with the rectum, and in the female with the uterus and upper part of the vagina by much loose areolar tissue, which permits great freedom of movement of these parts upon one another.

The bladder is kept in its position by certain reflections of peritoneum passing over bands of white fibrous tissue, or *reflexions of the vesical fascia* (*true ligaments*), and by folds of peritoneum alone (*false ligaments*).

The anterior reflections of the vesical fascia constitute the *anterior true ligaments of the bladder.* These arise from the lower margin of the pubis on each side of the symphysis. They then pass over

the upper surface of the bladder. Many of these fibres are attached to the muscular fibres, and this ligament may be said to serve as the tendon of attachment of many of the fibres which constitute the detrusor urinæ muscle.

The fundus of the bladder is connected with the umbilicus by the suspensory ligament of the bladder, a reflection of peritoneum which encloses the obliterated hypogastric arteries and urachus.

The muscular coat of the bladder is composed entirely of unstriped fibre-cells, which are much interwoven, but may be described as arranged in two layers, an external longitudinal, and an internal transverse or circular.

The latter are exceedingly numerous round the neck of the bladder, whence they have received the name of Sphincter Vesicæ.

The longitudinal fibres are most abundant upon the anterior and posterior surfaces of the bladder, and constitute the *detrusor urinæ* muscle.

The *mucous membrane* is of a pale colour, and is loosely connected to the muscular tissue by the intervention of much loose areolar tissue, in which the yellow element is abundant, except over the trigone, where it adheres very firmly, by which a perfectly smooth surface is produced in this situation.

About the neck of the bladder are a number of small glands, each consisting of a few secreting follicles, opening into a short wide duct. These are lined with columnar epithelium, and secrete a perfectly clear transparent mucus.

Epithelium.—The epithelium of the bladder varies much in its character in different situations. Near the orifices of the ureters it is almost entirely of a columnar form; but over the fundus, generally, it consists of large circular and oval cells, with a distinct nucleus. These are of very large size, and present a very characteristic appearance. Kölliker describes many of these large cells as lying upon the surface of columnar epithelium, their deep aspect being hollowed out to receive the summits of the latter cells. Towards the urethra, the columnar epithelium again predominates. Epithelium from various parts of the mucous membrane above referred to is often found in the urine; and the characters are often so distinctive as to enable the observer to infer with accuracy the locality from whence it was derived, a point which is occasionally of some value in diagnosis.

We shall consider the anatomy of the urethra, and other organs connected with the bladder, in the chapter on the *Organs of Generation.*

The student should consult the following works and monographs for more detailed information upon the subjects treated of in the present chapter: M. Malpighi, de Renibus, 1669; Schumlansky, de Structurâ renum, 1788; W. Bowman, in the Philosophical Transactions for 1842; Goodsir, in the Monthly Journal of Medical Science, 1842; Dr. Johnson's article, "Ren," in the Cyclopædia of Anatomy and Physiology, and his work on Diseases of the Kidney; and the treatises on Physiology and Minute Anatomy before referred to.

Upon the Urine.—Dr. Golding Bird, on Urinary Deposits; Dr. Bence Jones's Lectures upon Animal Chemistry; Lehmann's Handbuch der Physiologischen Chemie,

Leipzig, 1854; translated by the Cavendish Society. J. E. Bowman, Medical Chemistry. Beale, on the Microscope, and its application to Clinical Medicine, Chapter XIV.

CHAPTER XXXV.

ON THE DUCTLESS GLANDS.—SPLEEN.—ITS CAPSULE.—TRABECULAR TISSUE.—SPLEEN PULP.—SPLENIC ARTERY.—MALPIGHIAN CORPUSCLES.—VEINS OF THE SPLEEN.—LYMPHATICS.—NERVES.—CHANGES IN THE BLOOD IN THE SPLEEN.—USES OF THE SPLEEN.—SUPRA-RENAL CAPSULES.—THYROID BODY.—USES OF THE THYROID.—THYMUS.—USES OF THE THYMUS.

We have now to consider a remarkable class of organs present in all the mammalia, which resemble the secretory glands already described in external conformation and in the possession of a solid parenchyma, but differ from them in the absence of any excretory apparatus suitable for carrying off the products of secretion. These organs cannot be associated with such structures as the liver, the kidneys, and the other glands; inasmuch as they not only differ from them in the essential particular just mentioned; but they exhibit in their internal structure no mechanical arrangement clearly adapted to a secretory function; nor is any material (save in the case of the thymus) to be obtained from them bearing any resemblance to a secreted product. Many physiologists, however, suppose that these organs do exert an attractive influence on certain matters in the blood, and separate them from it; but this hypothesis necessarily involves a second and a less plausible one, that the matter thus extracted must re-enter the circulation.

These bodies agree in the common characteristic, that their parenchymatous portion consists of cells and cell-nuclei, with bloodvessels in great number variously disposed. They may probably be regarded as appendages to the vascular system, and, from the absence of any excretory duct, they are usually designated *vascular ductless glands*: under this head are grouped—the spleen, the supra-renal capsules, the thyroid body, and the thymus.

Spleen.—The spleen is of an oval form and somewhat compressed; its internal surface is concave, and its external surface is in contact with the diaphragm. The spleen lies in the left hypochondrium, and extends upwards as high as the tenth rib, but when enlarged reaches much higher, and increases upon the lower part of the thoracic cavity. The spleen is of a dark red colour, highly vascular, and of a soft pulpy consistence; it varies much in size, according to the state of general nutrition, and also at different periods of the digestive process. The weight of the spleen compared to that of the body at birth, is as 1 : 350, in adult life, 1 : 320, and in old age, as 1 : 700. The following points have to be noticed in considering the structure of the spleen:

the capsule, the trabecular tissue, the spleen pulp, or proper splenic parenchyma, and the arrangement of the arteries, veins, nerves, and lymphatics.

Capsule of the Spleen.—The spleen is covered by a reflection of peritoneum, which extends to it from the fundus of the stomach, and is called the gastrosplenic omentum. The proper capsule of the spleen is composed of white and yellow fibrous tissue, and permits of considerable distension. It envelops the organ entirely, and is prolonged into the interior upon the vessels, which are inclosed in sheaths composed of a structure closely resembling the capsule of the organ. In man there is an absence of muscular fibre-cells in the capsule, but in the dog and pig, and some other mammalian animals, they are very numerous.

Trabecular Tissue of the Spleen.—If a section of a spleen be carefully washed under a stream of water, the dark coloured, soft, pulpy matter is removed, and a perfectly white and complicated fibrous meshwork remains. The interspaces bounded by these trabeculæ vary much in size and form; but they are all intersected by still smaller trabeculæ, and these smaller spaces by fibres visible only by the aid of the microscope. The network thus formed, much resembles that of the corpora cavernosa penis, and the fibres composing it are intimately connected with the fibrous capsule of the organ, and also with the sheaths of the vessels supplying it. The spaces or interstices communicate freely with each other, and in them is situated the pulpy tissue of the spleen.

Fig. 245.

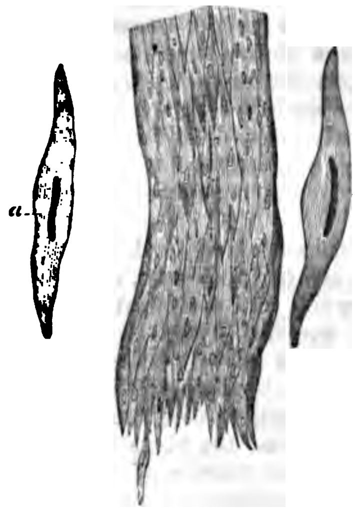
Cells from the trabecular tissue of spleen of human fœtus at full time. Magnified 215 diameters.

The larger trabeculæ, like the fibrous capsule of the organ, are composed chiefly of white fibrous tissue, with some fibres of the yellow element. The smaller trabeculæ are composed of elongated spindle-shaped cells, about the 300th of an inch in length, and about the $\frac{1}{5000}$th of an inch broad in the centre, which is their widest part. They contain a distinct elongated or oval nucleus. The nucleus is often found bulging upon one side of the fibre cell, and in some instances appears only connected with it by a stalk. The cell is often much curved, and sometimes bent upon itself, an appearance arising from its mode of development, which takes place, according to the observations of Mr. H. Gray, by the solution of the cell wall at a point opposite the nucleus, which latter remains, and the cell wall itself forms the fibres which are prolonged from either side of it.

In several of the mammalia, both in the capsule and also in the trabeculæ, a number of muscular fibre cells, with a distinctly oval elongated nucleus, are present. The fibre may be entirely composed of these cells. They are not present in the human spleen, but may be readily demonstrated in that of the sheep. The spleen possesses very slight power of contractility, and in experiments upon the spleen of the ox and sheep, Mr. Gray was unable to obtain marked contractions by the application of a strong galvanic current.

Spleen Pulp.—The spleen pulp, or parenchyma, the proper tissue of the spleen, is composed of peculiar colourless cells, containing masses of colouring matter, free coloured particles, granular matter and blood corpuscles.

Fig. 246.



Muscular fibre cells from the spleen of the sheep, magnified 400 diameters. *a, a.* Fibres more highly magnified. After Mr. Gray.

The *colourless portion* of the spleen pulp is composed principally of small circular cells, or nuclei, about the size of a blood corpuscle, and having a faintly granular appearance. These small nuclei vary somewhat in size, and are interspersed with a considerable quantity of granular matter, which is often collected around them. The spleen pulp also contains a few nucleated vesicles, nearly $\frac{1}{1000}$th of an inch in diameter.

These colourless elements constitute a considerable proportion of the spleen pulp, and are in contact with the capillary walls, and with the Malpighian corpuscles of the spleen. Great variation occurs in the size and general character of the cells and nuclei which compose the colourless elements, and they vary much in quantity in different physiological conditions of the system. Mr. Gray has shown, that in well-fed animals they are much more abundant than in those supplied with an insufficient quantity of food, and their proportion increases after the completion of the digestive process.

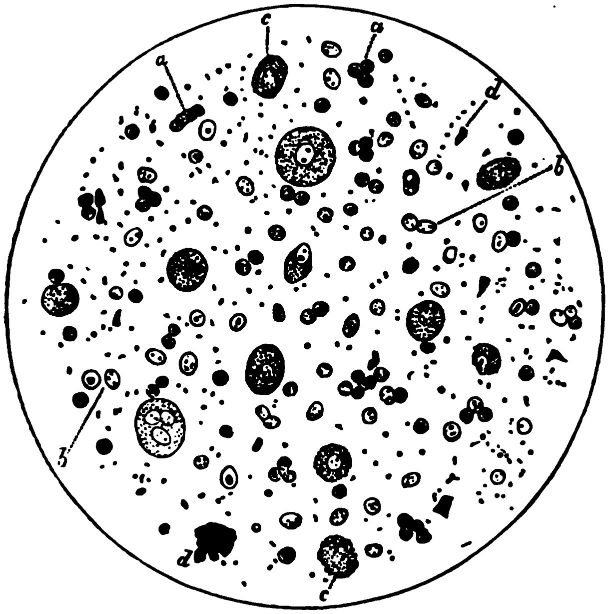
They are composed of a proteine compound, and in their chemical characters closely resemble the white corpuscles of the blood.

The red colour of the spleen pulp is due to the presence of a great number of blood globules and coloured corpuscles, free or contained within cells.

The blood globules are frequently observed to be smaller than in other situations; their outline is often indistinct; sometimes their surface appears corrugated or shrunken, and their walls in some places collapsed; their outline is irregular and angular, and in many instances corpuscles are seen evidently breaking up into small irregular masses of red colouring matter. These appearances indicate that the red blood corpuscles are undergoing a process of disintegration, but this change also appears to be effected in another and very peculiar manner, which was first described by Kölliker. Several blood corpuscles (from one to nine or ten) collected together, appear to become covered with an investing membrane, adhering to the interior wall of which, a distinct nucleus may be observed. Such appears to be the manner in which these blood corpuscle-holding cells are

formed, but whether the nucleus precedes the formation of the cell or succeeds it, is not known. The blood globules within now undergo disintegration in the manner just referred to, and at length the cell contains only coloured granules, varying in size and form. These granules gradually become of a golden yellow colour, and then paler, until at last the contents of the cell become almost decolourized.

Fig. 247.



Pulp of the human spleen. *a, a.* Blood corpuscles. *b, b.* Dotted nuclei. *c, c.* Nucleated vesicles. *d, d.* Coloured corpuscles of hæmatine. From Gray on the Spleen.

Occasionally, red crystals are seen in the blood corpuscles of the splenic parenchyma, as was first observed by Funke; and not unfrequently numerous free coloured acicular crystals are met with.

These appear to be the most important changes which take place in the disintegration of the red blood corpuscles in the spleen pulp. In some animals, the disintegration seems to occur entirely within the large cells; while in others, the blood corpuscle-holding cells are very rarely met with, and the blood globules become broken down into coloured granules without being at any time enclosed in a cell. In other cases, again, both processes occur. In the course of very numerous observations upon the human subject, Mr. Gray only observed blood corpuscles enclosed in cells in two instances, and then in very small number.

We may observe here, that Gerlach interprets these facts in a totally different manner, and considers that the changes taking place in the blood corpuscle-holding cells occur in the reverse order to that which we have described. In fact, he considers that the blood

corpuscles are *formed* in these cells, commencing as irregular yellow granules, and gradually becoming developed into the perfect red blood globule. In this view Virchow appears to coincide. Dr. Hughes Bennett, of Edinburgh, also considers the spleen as a blood-forming organ.

The changes above referred to take place in the spleen pulp which lies between the trabeculæ, and, of course, external to the capillary vessels. Now, we have to inquire how the blood corpuscles leave the vessels and enter the pulp.

Mr. Gray has shown that many of the capillary vessels are not directly continuous with the veins, but that the blood, in passing from one set of vessels to the other, traverses intercellular spaces in the spleen pulp. The veins also, in many cases, appear to commence in intercellular spaces, so that it is not difficult to conceive how the contents of the vessels extravasate into, and become mixed with, the constituents of the pulp, especially when the organ is distended with blood. These changes appear also to take place to a more limited extent within the veins themselves. Although this may be the correct explanation of the manner in which the cells in the pulp communicate with the blood in the vessels, we cannot look upon it by any means as demonstrative.

Splenic Artery.—The splenic artery is the largest branch of the cœliac axis, and the size of this vessel in proportion to the organ to

Fig. 248.

Transverse section of the human spleen, showing the mode of distribution of the arteries, and the manner in which their sheaths are formed. After Mr. H. Gray.

which it is distributed, is considerably larger than that of other glands, with the exception of the thyroid. The large size of the vessel would lead to the inference that more arterial blood is distributed to the spleen than is required for the mere purposes of nutrition. The branches of the artery are invested with sheaths derived from and continuous with the fibrous capsule of the organ, and they

a similar structure to it. Each arterial branch is distributed particular part of the organ, and it does not anastomose with iguous branches. The smaller arteries, about the $\frac{1}{250}$ of an inch iameter, are connected with the Malpighian bodies, which are lly placed in the points of bifurcation of the vessel.

'alpighian Corpuscles.—Upon making a section of a fresh ox's en, a number of small round whitish bodies will be seen. They sometimes collected in groups of four or six together, and appear connected with the smaller arteries, which are in close proxy to them. These small bodies have been named Malpighian uscles from their discoverer; they are in close contact with the en pulp, except at the points where they are in connection with coats of the artery.

he Malpighian corpuscles are very distinct in pigs, sheep, oxen, guinea pigs. In most other mammalia they are to be demon-ted, although with greater difficulty. In the human subject they constantly present; but often are not to be distinguished in con-ience of rapidly undergoing post-mortem change. In birds, these es are very numerous, and have been observed, by Müller, in chelonia, among reptiles, but they cannot be seen in the naked hibia. In fishes, they appear to be absent.

Fig. 249.

s figure shows the connection of a splenic corpuscle with the neighbouring vessels, according to [. Gray. The corpuscle is placed at the angle of bifurcation of one of the small arteries, its ex-l surface being covered by a close and delicate capillary plexus, whilst its circumference is in-d by a mesh of large veins, which radiate in every direction from its margins. The compara-ize of the arteries and veins, the capillary plexus of the pulp, and the mode in which these ls communicate with the veins, are shown in this figure.

The splenic corpuscles are placed upon a small branch of the arteries as upon a short peduncle or stalk, which sometimes consists only of fibrous tissue, prolonged from the sheath of the vessels, or they lie in the angle formed by the divergence of two branches from each other. The artery divides into numerous branches upon the surface of the Malpighian corpuscles. The observations of Kölliker and Dr. Sanders, which have lately been confirmed by Prof. Huxley, have shown that the substance of the corpuscle itself is traversed by small capillary bloodvessels. These small vessels probably pour their blood into small veins which surround the corpuscle, and are of considerable size. According to Mr. Gray, these veins receive the secretion of the Malpighian bodies.

The Malpighian corpuscle does not appear to us to be invested with a distinct and well-defined membranous capsule; but we are inclined to agree with Remak and Leydig, who represent their contents as not being separated by any distinct line of demarcation from the splenic pulp, although the fibrous tissue derived from the external wall of the vessels appears to form a sort of imperfect capsule. The cells of which these bodies are composed readily pass from them into the pulp. Mr. Gray has made the interesting observation, that these bodies are very large, and well defined in well-fed animals, and that, during the latter part of the digestive process, they increase in size, while, in animals insufficiently fed, they are very small, or absent altogether. In the latter, little increase is noticed in their size after digestion. Their increase is considerable under the influence of an albuminous diet; but when animals are confined to fat or gelatine, these bodies are not to be distinguished.

Veins of the Spleen.—The splenic vein is the largest branch of the vena porta, and, like the others, is destitute of valves. The branches into which the vein divides, do not communicate with each other in the substance of the organ. Mr. Gray describes three different modes in which the veins commence: 1. As continuations of the capillaries of the arteries, which is the most common method: 2. By intercellular spaces in the substance of the spleen pulp through which the veins communicate with each other. The smallest veins commence in this manner; or 3. By forming an imperfect capsule to each Malpighian body. This latter mode of commencement has not been described by other observers, and Mr. Gray considers these small veins as the channels by which the secretion of the Malpighian bodies is carried into the circulation.

The vein ramifies abundantly upon the surface of the spleen, and, as it enters into the organ, receives an investment of fibrous tissue, which is prolonged upon the branches, forming their sheaths, which are connected with the trabeculæ.

Lymphatics.—But little is known of the ultimate arrangement of the lymphatics of the spleen, or of the manner in which they commence. They are certainly not connected with the Malpighian corpuscles, nor can we look upon them as the channels which carry off the secretion of the organ, a view which has been advocated by many observers.

Nerves.—The nerves of the spleen are derived from the splenic lexus formed by branches from the left semilunar ganglion, and rom the right pneumogastric nerve. The branches are distributed o the coats of the arteries; they may be traced upon them for a onsiderable distance, but gradually they become lost.

Changes in the Blood in the Spleen.—The most important pecuiarities in splenic blood appear to be the following: The total uantity of solid matter is considerably less in the blood of the plenic vein than in arterial or venous blood, and the blood coruscles are reduced to half the quantity. The greatest reduction eems to occur at the period of the greatest turgescence of the spleen. Ir. Gray has made the very interesting observation, that in starved nimals no change is observable. The albumen is increased, paricularly when the amount of blood corpuscles is much diminished. The quantity of fibrine in splenic blood, is also found to be increased. The serum is often observed of a pale reddish-brown colour.

Uses of the Spleen.—We have now to consider the uses of the pleen in the animal economy. From the large quantity of elastic issue in its capsule and trabeculæ, it seems eminently adapted to ndergo great changes in volume; and the direct experiments of Dobson, and many other observers, have proved that it becomes nuch enlarged during digestion, as well as when blood was injected nto the jugular vein. Connected with the large veins of the portal ystem, it forms a dilatable diverticulum, or reservoir, in which blood nay, for a certain time, be contained, thus preventing dangerous ongestion of the veins of the liver, and some other abdominal viscera, nd, indeed, of the venous system generally. The spleen does not ppear to be contractile. In several careful experiments, Mr. Gray vas never able to cause more than a slight corrugation of the surface f the organ by the galvanic current, although active contractions ould be produced in the œsophagus, or stomach, under similar ircumstances. In no instance out of twenty experiments, was lood expelled from the organ, or its diameter diminished. Not nly does the spleen perform this physical office, but, as has been hown, certain important chemical and microscopical changes are ound to have occurred in the blood which has passed through this rgan. In 1847, Kölliker advanced the theory that blood corpuscles ecame disintegrated in the spleen, an opinion which was afterwards upported by Ecker and Béclard. From various facts which we have lluded to, we cannot but look upon this point as decided in the ffirmative, although others have been led to adopt the view, that lood corpuscles are actually formed, instead of being disintegrated n this organ. Kölliker thought that the colouring matter of the lood was changed in the spleen, and converted into the peculiar olouring matter of the bile; but Mr. Gray has shown, that yellowishreen bile is found in the gall-bladder of the chick, at a period coniderably antecedent to the development of the splenic vein. The mall size of the spleen in the fœtus, as compared with its increase fter birth, and in adult life, renders it improbable that in intra-

uterine life it acts the part either of a blood-forming, or blood-destroying, organ.

Its great increase in size, in well-fed animals, and its diminution in insufficiently-fed animals, and, especially its increase after the completion of digestion, render it extremely probable that it has the power of storing up albuminous material for future consumption when a larger quantity of nutrient material is taken than is required for the immediate wants of the system. The cells of the Malpighian corpuscles appear, from Mr. Gray's observations, to be the organs especially concerned in this process.

Supra-renal Capsules.—The supra-renal capsules are two bodies of a somewhat triangular form, situated one on each side of the spine, a little above the corresponding kidney, to the capsule of which each is connected by loose cellular tissue.

Each supra-renal capsule is about an inch and a half in depth, somewhat less in width, and usually about half an inch in thickness. The weight varies from one to two drachms. The gland is inclosed in a thin fibrous capsule, which dips down into its substance. It is surrounded with loose areolar tissue, containing an abundant quantity of fat.

Upon making a section through the body, it is found to be composed of two distinct portions, a *cortical* and a *medullary part*. The former is of a yellowish colour, shading into a brown border towards the interior. It tears somewhat readily, and then exhibits a fibrous appearance. The medullary substance is of a paler colour, unless the vessels are injected with blood, and of a somewhat softer consistence. If the gland be not perfectly fresh, a cavity is usually seen in the interior, which results from the breaking down of the medullary tissue.

The cortex is divided into a series of compartments or tubes by septa of fibrous tissue prolonged inwards from the capsule of the organ. These spaces extend through the entire thickness of this part of the body, and pass from the surface vertically inwards. They contain numerous oval or spherical bodies, varying considerably in length. These have been looked upon by Ecker as gland-follicles, but Kölliker considers them merely as aggregations of cells not invested with a distinct membrane, or inclosed in a larger cell. They are separated from each other by meshes of areolar tissue, the fibres of which often appear to be connected with the surface of the mass. In the outer part of the cortex separate cells, filled with pigment granules, are usually to be met with; but in the inner portion, round or oval vesicles are found, which are filled with oil globules.

The medullary substance is composed of a network of areolar tissue which is prolonged from the cortex, and contains numerous vessels, in the meshes of which are found many cells, some of which contain fat or granular pigmentary matter. A distinct nucleus and commonly a nucleolus are seen, and often the cells have many angular processes, or are much branched; indeed, these cells present an appearance much resembling that of the nerve vesicle.

Besides the fibrous, vascular, and cellular elements just described,

ıe medullary portion of the supra-renal bodies is very largely supplied with nerve fibres derived from the semilunar ganglia and solar lexus, with a few fibres also from the pneumogastric, and from the hrenic. The nerves appear to perforate the cortical substance in ɪveral places, pass through this, and enter the medullary, where ıey form a plexus amongst the fibrous tissue. The mode of their ɪrmination has not been made out.

The function of these peculiar bodies is entirely unknown. From ıe great dissimilarity of structure observed in the cortical and ıedullary portions of the organs, it is probable that each performs distinct and separate office. In the present state of our knowledge e may continue to classify the former with the ductless or vascular lands, but, from the existence of cells much resembling nerve vesies, and an abundant plexus of nerve fibres, it appears more correct regard the latter as connected in some manner with the nervous rstem and probably with the sympathetic. Bergman thinks that ıis part of the supra-renal body may, perhaps, bear a relation to the rmpathetic, similar to that which the pituitary body does to the rain. It is interesting to note, in connection with this subject, that ır friend, Mr. Brown-Séquard, has observed congestion, and hyperophy of the supra-renal capsules, after injuries to the chord in the ɔrsal region.

Dr. Addison has lately published an account of several very inıresting cases of disease of the supra-renal capsules, associated with anæmic general languor and debility, remarkable feebleness of eart's action, irritability of the stomach, and a peculiar change of ɪlour in the skin."*

Thyroid.—The thyroid body, or gland, as it is sometimes called, a soft, and very vascular organ, situated upon the lateral aspect f the upper part of the trachea, as far upwards as the sides of the ɪrynx. It consists of two lateral lobes, united by a thin narrow ɔrtion, which has a similar structure to that of the gland itself, ɪtending across the front of the third or fourth rings of the trachea, ɪd known as the isthmus. The middle lobe, which varies somehat in position, is a thin process, extending upwards from the thmus, or one of the lateral lobes, and often reaches as high as ıe hyoid bone, to which it is attached by loose fibrous tissue; ıdeed, this process itself is not unfrequently composed of fibrous ssue only, and sometimes contains a few fibres of the thyro-hyoid ıuscle.

The thyroid body itself is made up of a vast number of small ɪbules, which are aggregated together in larger globular or oval ıasses, of which the entire substance of the gland is composed. hese are all surrounded by, and connected together with areolar ssue, and each subdivision itself consists of a number of small osed vesicles, between which the vessels ramify, also closely in-

* On the Constitutional and Local Effects of Disease of the Supra-renal Capsules, by ıomas Addison, M. D., Senior Physician to Guy's Hospital, 1855.

vested with areolar tissue, varying considerably in size, and containing fluid, or thick gelatinous matter.

Each vesicle may, therefore, be described as consisting of a fibrous coat, composed of areolar tissue, internal to which there exists a delicate basement membrane, lined by cells of epithelium, which vary somewhat in character, but usually are seen as polygonal, or almost circular cells of a faintly granular appearance, and having a nucleus, which, however, is by no means invariably present. In most instances, the vesicle can be seen to be lined with a single layer of this epithelium, and many free cells are usually found floating in the fluid contained in the cavity.

The fluid in the vesicles is coagulated by heat and nitric acid, and evidently contains a large quantity of *albumen*.

The stroma of the gland consists of fibres of both the white and yellow element, and it supports the bloodvessels, which are exceedingly numerous, and form a capillary plexus round each vesicle.

The lymphatics in the thyroid are numerous, but of their ultimate distribution nothing is known.

The following are analyses of the thyroid body, by Dr. Beale.*

	Human.	Ox.
Water	70·60	71·34
Solid matter	29·40	28·66
Fibrinous and albuminous matter, vessels, and fat	26·884	24·628
Extractive matter	1·70	—
Extractive matter, with gelatine	—	2·888
Alkaline salts	·50	·642
Earthy salts	·816	·502

Uses of the Thyroid.—Of the uses of the thyroid but little is known. The material found in the vesicles is of an albuminous nature. Mr. Simon has advanced the opinion that the thyroid acts as a diverticulum to the cerebral circulation, and that its nutrition bears a certain relation to that of the nervous matter of the brain. When the latter is quiescent, the thyroid is supposed to be active in removing from the blood, and storing up in its cells, certain constituents which are required by the brain only in its active state, and which are diverted to it when it resumes its activity. This view is based upon the important fact, that the arteries of the thyroid body arise in close proximity to those which supply the brain, the *superior thyroids* coming off from the external carotid, just immediately above the point of bifurcation of the common carotid, and the *inferior thyroid* arteries, from the subclavian, almost immediately opposite the origin of the vertebrals.

Thymus.—The thymus body or gland is an organ only distinctly recognizable during early life. It appears to reach its largest size between the first and third years; but much variation occurs in this point in different individuals. It lies partly in the thorax and partly in the neck, and is composed of two lobes, which vary considerably in size, sometimes the right and sometimes the left being the largest.

* Dr. Handfield Jones, article "Thyroid," Cyclopædia of Anatomy and Physiology.

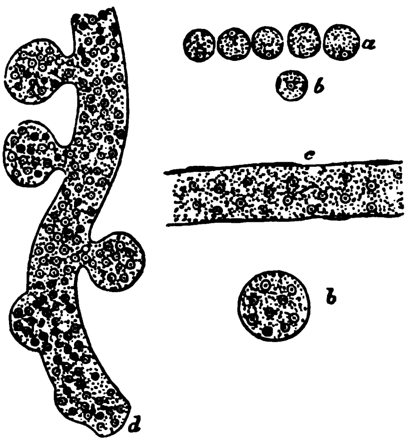
The organ rests upon the front of the aortic arch and large arteries rising from it, and also on the left vena innominata. It is covered by the sternum, and at birth reaches down to the fourth costal cartilage. It extends upwards into the neck, as high as the thyroid body, and lies upon the front and side of the trachea.

The researches of Sir Astley Cooper, and more recently those of Mr. Simon, show that this organ consists essentially of an elongated tube, from all sides of which extend numerous small follicles or sacculi, which pour their contents into the central cavity. Sir Astley Cooper unravelled the gland, and, by having previously injected the central cavity and follicles with alcohol, or coloured size, was enabled to make out their relations and arrangement; although, by these processes, it is probable that he distended the central cavity to a greater extent than natural, and was thus led to look upon it as much more extensive than it was subsequently proved to be by the conclusive observations of our friend Mr. Simon, which are published in his well-known essay.

The latter excellent observer, carefully watched the development of this gland, and thus was the first to make out accurately its anatomy.

It is probable that it first arises from a row of cells arranged in linear series, which coalesce, and thus become converted into a narrow tube. The wall of this tube then bulges at intervals, and vesicular cavities are gradually formed. These vesicular dilatations are much more abundant in some situations than in others; and the primary offset divides in a dichotomous or quaternary manner, until, from the number and irregular distribution of these vessels, the gland assumes its ultimate shape and character. The closed cavity of the gland contains granular matter, with numerous nuclei dispersed through it. In a thin section, the outline of the cavities can be readily seen; they vary from the 1-50th to the 1-18th of an inch in diameter, and contain numerous granular and nearly spherical nuclei, which are, for the most part, about 1-4000th of an inch in diameter, but vary considerably in size. Dr. Handfield Jones observes that before any appearance of atrophy has taken place, these elements are alone found, and there is an entire absence of oil particles, and granular material. The nuclei seem to fill the ultimate vesicles completely.

Fig. 250.

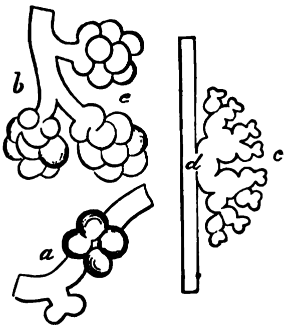


a. Primordial cells in a row. *b.* Isolated cell, unconnected with the row, and undergoing development in its original cell shape. *c.* Primary tube, formed by the fusion of the cells. *d.* Second stage of development of the thymus, showing bulgings of tube in different stages, which ultimately become themselves divided. After Simon.

Uses of the Thymus.—Mr. Simon regards the secretion of the thymus as allied to proteine, and of a nutritious nature.

In the human fœtus, the thymus cannot be detected before the ninth week, and its functional activity is greatest in the early period of life, before the muscular system is in a very active state; for when the muscles become more fully active, the thymus appears not to be required. It seems connected with the preparation of matter for the pulmonary organs in the "age of early growth." Arguing from these and many other facts, Mr. Simon looks upon the thymus as acting "as a sinking fund in the service of respiration." From the twentieth to the twenty-fifth year it diminishes rapidly in size, until no trace of it can be detected in the areolar tissue of the mediastinum. In hibernating animals, previous to the commencement of the winter sleep, the thymus becomes gorged with fat, which is slowly consumed during the period of hibernation. It has been remarked, that the use of the thymus at the different periods of active growth and hibernation is distinct. In the latter case, it doubtless supplies hydro-carbonaceous matter for respiration; but its office, during the former period, appears rather to be that of elaborating fibrine from albumen and other substances by the action of its numerous nuclei. As the absorbent and other glands connected with the vascular system become developed, there seems no longer any need of a special organ for this purpose, and consequently the thymus soon disappears. Professor Paget and Dr. Handfield Jones express themselves in favour of this latter view. In the present state of our knowledge, perhaps no better hypothesis of the office of this gland can be suggested. The whole subject of the physiology of the vascular ductless glands (if glands they be) is involved in deep obscurity, and it is impossible to form a theory of their respective functions which is perfectly satisfactory. Not less obscure are their morbid conditions, upon which the improved anatomy of the last few years has thrown but little light.

Fig. 251.



a. Binary and quaternary division of simple follicles. *b.* Unusual appearance, in which the follicles must have increased considerably in length before undergoing division. From the fœtal lamb.
c. Mature structure of thymus, showing the arrangement of the vesicles belonging to one cone. *d.* Tube of gland. After Simon. Reduced.

The student is referred to the following works for a more detailed statement of the various views now held upon the anatomy and physiology of the vascular glands.

Spleen.—Kölliker's "Mikroscopische Anatomie," and the Article "Spleen," in the Cyclopædia of Anatomy and Physiology; Ecker's Art. "Milz," in Wagner's Handwörterbuch; Sanders "On the Structure of the Spleen," in the Annals of Anatomy and Physiology; Bennett "On Leucocythemia:" Mr. Gray's Astley Cooper's Prize Essay upon the "Structure and Use of the Spleen," 1854; Mr. Simon's Astley Cooper's Prize Essay on the "Thymus Gland," 1845; also his paper upon the "Thyroid," Phil. Trans., 1844; Dr. Handfield Jones' Articles "Thymus" and "Thyroid," in the Cyclopædia of Anatomy and Physiology.

CHAPTER XXXVI.

ON GENERATION.—FISSIPAROUS MULTIPLICATION.—GEMMIPAROUS MULTIPLICATION.—TRUE GENERATION.—METAMORPHOSIS.—METAGENESIS, OR ALTERNATION OF GENERATIONS.—SEXUAL ORGANS.—INVERTEBRATA.—INFUSORIA.—POLYPS.—ACALEPHÆ.—ECHINODERMATA.—ENTOZOA.—ANNELIDA.—MOLLUSCA.—CRUSTACEA.—INSECTA.—PISCES.—REPTILIA.—AVES.—MAMMALIA.

Amongst the lower classes of organized beings, both in the animal and vegetable kingdom, the multiplication of individuals, or the propagation of the species, is provided for by three different processes, while in the highest forms of animal life the process of generation is restricted to one of these types.

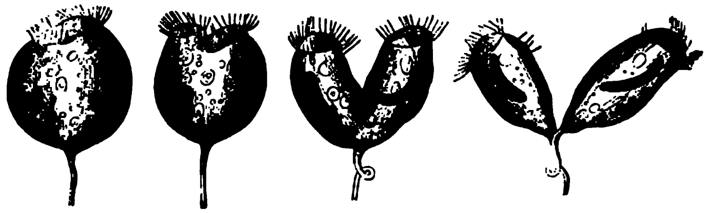
The simplest manner in which the multiplication of individuals takes place, consists in the division of the being into two, each of these again dividing into two others, and so on; this is multiplication by fission.

The second mode of increase consists in the formation of a bud at some part of the body of the parent: this bud is gradually developed, drops off, becomes independent of its parent, and ultimately assumes a perfect form, resembling in all particulars that from which it sprung.

The third mode differs materially from the two former, in the fact, that the new organism results from a series of changes occurring in an impregnated ovum, which is produced by the mutual action of the contents of two dissimilar cells, the products of distinct parental organs. The new body differs essentially from either of the two cells which produced it. This is *true generation.*

Fissiparous Multiplication.—In the lowest plants, such as the lichens and fungi, this mode of multiplication very commonly occurs. The cell, or cells, of which the plant consists, divide and subdivide; and, in this manner, new organisms are produced. The same mode of reproduction is also seen to be very common amongst the infusoria, and may be watched in the common vorticella.

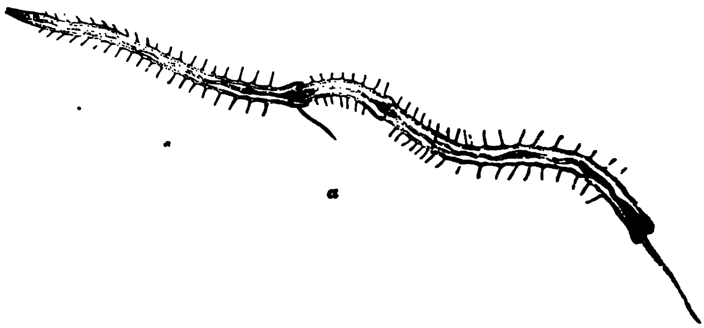
Fig 252.



Vorticella Microstoma multiplying by spontaneous longitudinal division, from Ehrenberg.

The joints of the common tape-worm multiply in this manner, and after a time, when perfectly developed, become free and separate from the trunk of the worm. Amongst the worms (Annelida) reproduction takes place partly in this manner. In the Naïs, three or four young worms, resulting from the division of the parent, may often be seen still connected with its body. As these become developed, they are disconnected from the parent, and, in their turn, give rise to others by a similar process.

Fig. 258.



Naïs proboscidea, multiplying by spontaneous transverse division, showing the body of the parent worm and three young ones in different stages of development. *a*. Point at which new segments are being formed. After Müller.

In the above instances, multiplication by division occurs as a natural process; but there are many instances in which the parts resulting from *artificial* division ultimately become developed into a perfect animal. Thus a planaria, or a polyp, may be divided into many segments; and each portion has the power of absorbing to itself nutriment, and of becoming developed into a perfect form. The slightest handling, again, causes some animals to break up in pieces, and each separate part becomes a new being.

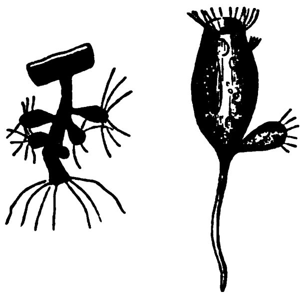
Multiplication by Gemmation.—A bud consists of a mass of cells, which possess the power of development, under favourable circumstances, into a form identical with that from which they were produced. In consequence of this property, the bud of a plant has been termed a *phyton;* and a tree must, therefore, be looked upon as an assemblage of these phytons. We must, however, bear in mind, that all buds have not this power, as, for instance, flower buds do not give rise to the formation of new buds of any sort, but produce seeds.

Amongst the lower animals, reproduction by buds is very common, and can be readily examined in the vorticellæ and polyps.

In the hydra, the first change which is observed consists in the formation of a little elevation which soon becomes globular; next a cavity is formed in this globular mass, and becomes continuous with that of the parent. After a time the channel of communication closes, and the bud begins to assume the form of a polyp, which ultimately drops off; and in this way a new creature is formed. The

ococci multiply by the formation of upon the internal surface of the tid vesicle. At first they are at- d by a sort of stem; but ultimately become free, and move about in luid of the parent cyst by aid of hooks and suckers.

Fig. 254.

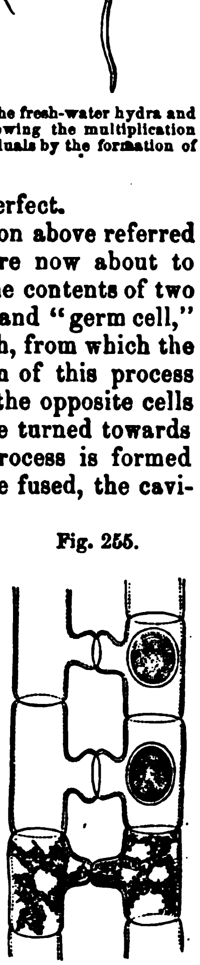


Figures of the fresh-water hydra and vorticella, showing the multiplication of new individuals by the formation of buds.

bud differs from an ovum in the :tant particular, that it contains ı itself the power of development, the latter is incapable of becom- eveloped into the form of its pa- until it has been subjected to the ı of the contents of another cell. only resemblance between a bud n ovum is, that in both the organization is imperfect.

ue Generation.—The processes of multiplication above referred ıst be distinguished from the one which we are now about to ler. True *generation* consists in the union of the contents of two ent cells, called respectively the "sperm cell" and "germ cell," he production of a structure differing from both, from which the)eing is ultimately evolved. The simplest form of this process n in the lower algæ in *conjugation*. At first, the opposite cells o filaments are seen to be swollen on the side turned towards other; the swelling increases until a sort of process is formed each: these at length meet; the walls become fused, the cavi- ontinuous, and the contents of the two cells ıe mixed. From this admixture a new body, d a *spore* or *sporangium*, results, by the de- ment of which the new plant is formed.

Fig. 255.



Conferva bipunctata in the act of conjugation, after Meyen. The cells from contiguous filaments approach each other, and ultimately their cavities coalesce. The oval spores resulting from the action of the contents of one cell upon the other are seen in two of the cells.

the higher plants and in animals, distinct s are set apart for the formation of the sperm and germ cells. By the action of the con- of the sperm cell the ovum becomes impreg- ; and under favourable circumstances, often independent of the parent, changes result give rise to the formation of the embryo which the adult animal is gradually deve-

w, either the perfect form of the being may ained by the gradual and progressive deve- nt of the embryo, or several distinct *phases istence* may be passed through before the ıre reaches its perfectly developed form. atter condition is seen in many of the lower s of animals, and is familiar to us in the of insects; it is, in fact, what we understand *tamorphosis.*

tamorphosis.—In metamorphosis, it must be ılly borne in mind, that it is the self-same

embryo which passes through certain transitional stages or phases, and ultimately becomes the perfectly developed animal; a condition essentially different from that which we shall next consider under the term *Metagenesis*, or *alternation of generations*, in which successive generations of larval creatures are produced from larvæ without the occurrence of any fresh generative act. Here, instead of one individual passing through several transitional forms, an imperfectly developed creature produces a multitude of forms, resembling either itself or the perfect individuals from which the ovum was formed which evolved it.

Metagenesis.—In some animals, the embryo, instead of being developed into a form resembling that of its parents, only attains a sort of larval condition, the offspring of which, however, return to the perfect type, instead of assuming the character of their larval patient. Now, between the fully-developed animals of one generation and those of the next succeeding there may be several series of these imperfect or larval forms; each larva producing without any generative act, and, indeed, without itself possessing true generative organs, many similar larval forms, until at last these larvæ, instead of producing larvæ, give rise to perfect forms, which propagate only by the production of ova.

This curious phenomenon occurs amongst many classes of animals; and the subject of late years has engaged the attention of many naturalists. Steenstrup has described the process under the term *alternation of generations*. Owen terms it *metagenesis* and *parthenogenesis*. The facts have been explained differently by different observers; the two most important theories being the following: according to the first, the subsequent broods result by a process resembling budding, taking place within the bodies of their predecessors; while the second supposes that a portion of the original germ-mass is actually transmitted from the parent through the whole series of beings existing between two generative acts. The latter view has been most ably advocated by Professor Owen, in his lectures on *Parthenogenesis;* and the former is supported by Dr. Carpenter. In the Campanularia dichotoma, one of the tribe of polyps, at certain periods, buds are developed from the stem, which do not become converted into polyps, but, after having reached a certain stage of development, drop off, and in their mature state are seen as transparent disc-like bodies, having the power of swimming about in the water. These creatures have long been known as Medusæ, or jelly-fishes. It must be remarked, that no generative organs are to be found in the polyp; but these organs are found in the Medusæ, in which also ova are developed. The ova become polyps, which eventually put forth Medusa-buds as before.

In another polyp, the Strobila, at certain periods, multiplication by the formation of buds ceases, and the body of the polyp becomes constricted, and at the same time much elongated. The constrictions, which may be as many as forty in number, gradually become deeper, until at length the body of the polyp becomes divided into a number of flattened discs. The terminal disc drops off, and appears

as a free swimming Medusa, in which generative organs are found and ova produced. The other discs fall off successively, and in like manner become Medusæ. These polyps, therefore, would with propriety be considered as belonging to the class Acalephæ, the Medusa representing the perfect condition of these animals.

The livers of various animals are infested with an entozoon termed a fluke. The development of the fluke of the common fresh-water snail (Limnæus stagnalis) presents us with a beautiful example of the curious phenomenon we are now considering. In the first stage of its existence it is seen as a creature (Cercaria) swimming about in the water, and is provided with a tail. After a time, these cercariæ fix themselves to the skin of the snail by means of a circlet of hooks. The tail is cast off, and the body becomes covered with mucus, which hardens, until a transparent case is formed. This is the pupa state. Next the creature bores its way into the body of the snail, and reaches the liver; the hooks drop off, and it possesses all the characters of a fluke or distoma. The fluke develops ova; the ova become developed into worm-like creatures, which inhabit the snails. The worm-like body contains, as it were, a progeny, each member of which becomes the parent of another generation. The original larvæ are developed from a perfectly spherical germ, consisting of granules. So that the early stages of life of the fluke are passed in the body of a worm-like creature; the next, in the water, free; next, attached to the body of a snail; and lastly, in a perfectly developed form in the liver. Thus this creature assumes three distinct forms at different periods of its existence, which, until these discoveries were made, had been described as three distinct creatures.

There are numerous other most striking instances among the entozoa of this extraordinary change of character in the course of development. It has long been known that the cystic entozoa (as Cysticercus, etc.) are not provided with generative organs; but it was reserved for Van Siebold to show that these entozoa were only the imperfectly developed forms of species occupying a higher position; and he has been able to prove that the *cysticercus fasciolaris*, which is found in the liver of the rat and mouse, becomes developed in the intestine of the cat into the *tænia crassicollis*, the common tape-worm of that animal. Kuchenmeister and Van Beneden have been able to demonstrate the occurrence of similar changes in many other entozoa.

Another beautiful example of *metagenesis* occurs among the members of a much higher class of animals—insects. The ovum of the perfect winged aphides, or plant lice, becomes developed into an imperfect wingless, or larval creature, in which no sexual organs have been discovered. These viviparous, but non-sexual larval forms are capable of producing non-sexual descendants exactly resembling them, without the occurrence of any generative act, and this process is repeated for nine or ten generations. The last autumnal brood, however, of these larvæ produce, in the same viviparous manner, perfect male and perfect female insects, with fully developed sexual organs. The female deposits her ova in the axils of the leaves and

other protected parts of the plant, where they remain until the following spring, when they are hatched, and the larvæ above described issue forth; the first larva producing eight, and each of these repeating the process, until, in the course of the summer, millions of larval forms are produced. This must conclude our very imperfect sketch of these interesting processes; and, for more detailed information, we must refer the reader to the works enumerated at the end of the present chapter.

Professor Owen considers that the larval forms result from the development of a portion of the original germ-substance of the yolk, which was not converted into a portion of the textures of the beings which resulted from the immediate development of the ovum; and hence he has applied the term *parthenogenesis*, or virgin generation, to this process of development. Dr. Carpenter, on the other hand, looks upon the process as akin to gemmation, or budding, rather than one of *actual generation*. Victor Carus shows that in this process of development the embryo is formed from a granular germ, whereas ordinarily it results from the process of cell-multiplication, as will be shown in the chapter on the development of the embryo. The same author contrasts the process of metamorphosis and metagenesis in the following words: "Larvæ, the subjects of metamorphosis, arrive at the state of perfection by throwing off provisional structures which belong to their larval condition; but nurses,* the subjects of metagenesis, are themselves entirely provisional structures."

In the present state of knowledge, it is difficult to group these extraordinary phenomena under one general head. Although we may contrast the processes of metamorphosis and metagenesis with each other, and draw definite distinctions between them, we must remember that there are instances in which both these processes occur; and although metamorphosis affects a single individual, and metagenesis a very numerous progeny, we do not feel ourselves in a position to define the exact relation which one bears to the other, and we think it better to avoid any attempt at generalization until a greater number of facts relating to these wonderful processes should be discovered, rather than adopt a view which future research may show to be erroneous.

Sexual Organs.—The generative organs are of two kinds, the male and the female organs, the one secreting the "sperm cell," and the other the "germ cell." The generative apparatus consists of two parts: a formative organ, in which the elements are produced, and which is *essential;* and an efferent duct, by which the products of secretion are carried off.

The male and female organs may exist in one individual or in separate individuals. The first condition is termed *unisexual*, and the second *bisexual* generation.

In some unisexual or hermaphrodite animals, self-impregnation

* The term "nurse" was originally applied by Steenstrup to these larval forms, but we have purposely avoided its use, as it is for many reasons very objectionable, and likely to convey a wrong idea of the nature of the viviparous larvæ.

takes place, as is the case in the common tape-worm (Tænia solium); while in other instances, concourse is necessary in order that the ova should be exposed to the action of the spermatic fluid; this is the case with many of the mollusca, as the common snail, etc. In these instances, each hermaphrodite animal impregnates its neighbour.

Besides the secretion of the formative organ, other secretions are frequently poured into the efferent duct. The duct undergoes great modifications in different parts of its course in various animals, according to the particular office it has to fulfil. We shall now consider some of the most important characters which the sexual organs exhibit in the different classes of animals.

Invertebrata.

The *Infusoria* multiply by fission, and rarely by gemmation. No sexual organs have yet been discovered in them, and ova are not met with in this lowest class of the animal series.

Fission may occur in the longitudinal direction, as in the *Vorticella:* or transversely, as in *Stentor* and some others; or in both directions, as in *Bursaria*, *Paramæcium*, and others. The Vorticellæ are also propagated by the formation of buds. When division is about to take place, the cell within the body, known as the nucleus, is seen to divide into two; each half containing, therefore, a newly-formed nucleus.

The *Polyps* multiply by gemmation and by the formation of ova, very rarely by fission. In gemmation, the young polyp may be ultimately set free, as in the *Hydra;* or it may remain attached to the stem or common body, or polypidon, as in the majority of the members of this class. Some polyps are hermaphrodite, while in many the sexes are distinct. At the time when the common hydra is about to propagate by ova, the male and female organs are both developed as excrescences upon the outer surface of the body. Others, again, are sexless, and give rise to the development of medusa-buds, or split up into discs, as already described in p. 822.

Reproduction in the class *Acalephæ* takes place almost entirely by the formation of ova. It has, however, been shown by Professor Huxley, that some multiply by gemmation as well as by the production of ova (Diphyidæ). Some of the species are unisexual, and others bisexual. The genital organs are only developed at certain periods and the male and female elements are brought into contact through the influence of the water in which they swim.

In the *Echinodermata*, fission has only been observed to occur in one class (Holothuria); and the generative function, which is developed in this class to a great extent, is carried on almost exclusively by the production of ova. The sexes are distinct, but the ova are impregnated without sexual intercourse. In some there is a proper efferent duct; but in others the elements pass into the respiratory cavity, and thus escape from the body.

Among the *Entozoa* great variety is met with in the arrangement and character of the generative organs. Almost all the animals of this class possess true generative organs, and multiply by means of ova, but in many of them fission occurs; as, for instance, in the tape-worm; but it is worthy of remark, that the entire animal is not produced in this process. The segments, however, which have been separated continue to live. As already mentioned, the Echinococcus multiplies by the formation of buds.

Some of the Entozoa are unisexual, and have the power of self-impregnation, and some are bisexual.

The *Annelida* reproduce by sexual apparatus, and in some instances, as already referred to, by transverse fission. In the latter case, the different organs, including the tentacles and eyes, are developed before the new animal is separated from the old one. This mode of multiplication, however, only continues for a certain time; at length it ceases: genital organs, which before could not be distinguished, are developed, and ova are formed. The Hirudines and Lumbrici are hermaphrodite, but copulation is necessary for impregnation to take place.

Amongst the lower *Mollusca*, the sexes are sometimes united in one individual, and sometimes distinct. There are no copulatory organs, so that the water forms the medium by which the spermatic particles are conveyed to the ova. Amongst the Tunicata, multiplication also takes place by gemmation.

Of the higher *Mollusca*, some are hermaphrodite, and in others the sexes are distinct. Many families are characterized by the possession of what has been termed an hermaphrodite gland, which is almost always imbedded in the substance of the liver. This gland consists of numerous radiating and branched cæca. Each cæcum consists of an external and internal sac folded within the first. Ova are produced by the external sac, and spermatic particles by the internal one. Excretory ducts pass off from these organs, and terminate in two tubes; the one corresponding to the Fallopian tube, the other to the vas deferens. Besides this apparatus, there is also another organ connected with the excretory duct; this is the albumen gland, which furnishes a secretion in which the ova become imbedded as they pass towards the external orifice. This curious arrangement may be well seen in the common snail.

Into the same cavity or cloaca in which the genital ducts terminate, is found the opening of another very remarkable organ—the dart sac—in which a hard and excessively sharp-pointed, and sometimes toothed, calcareous body is formed, which is projected during copulation. The dart may be looked upon as an arrangement for producing sexual excitement, for each snail has been seen to prick the other just before coition.

Amongst the *Cephalopoda*, the highest of the Mollusca, the sexes are always distinct. Connected with the excretory duct of the ovary is an apparatus which furnishes a secretion by which the eggs are bound together, and a firm horny covering formed for their protection.

The testicle consists of an oblong organ, situated at the bottom of the cavity of the mantle. Connected with the excretory tube, is a sac in which some very complicated organs, containing the sperm, are developed, from which the contents are expelled by a very remarkable projectile apparatus. Coition appears to take place simply by one animal applying itself to the other. A true intromission of the penis seems hardly possible.

One of the most curious phenomena which has been discovered in connection with the generation of some of the members of this class must be briefly noticed here. On the male Argonaut is developed a curious elongated body, termed Hectocotylus, which communicates with the testicle of the Argonaut by a duct. Before this body had been proved to belong to the male Argonaut, and had only been seen upon the female, it was looked upon as a parasite, and Cuvier described it as one of the Trematoda. The Hectocotylus, which is to be regarded as one of the arms of the animal metamorphosed in a peculiar way, at length becomes filled with spermatic fluid, and drops off. It is now independent, and comes into contact with the female Argonaut, which it impregnates. In this point it resembles, "as also by its movements, by a kind of circulation, and by the long duration of its life after detachment, a true male animal" (H. Müller).

Among different families of the *Crustacea*, the arrangement of the generative organs varies much. In most, the sexes are distinct; but one class, Cirrhipeda, is hermaphrodite. Some Crustacea, again, are almost exclusively females; and these for many generations produce females, and at very long intervals only, males. Some families, again, lay two kinds of eggs, one of which becomes developed spontaneously, while the other requires to be fecundated by the spermatic fluid. The female of the Daphnia, towards the close of the year, produces two eggs, which must be looked upon in the light of gemmæ, or buds, as they contain no germinal vesicle. These are the so-called hibernating eggs, and are developed without the fecundating influence of the sperm.

Among the Crustacea, the genital organs are usually double, and symmetrical in both sexes. Connected with the efferent duct of the female organs are some glands, which secrete a viscid substance, by which the eggs are glued together in clusters to the posterior abdominal feet, as occurs, for the most part, among the Decapoda (lobster, etc.); but in those species in which these organs are deficient, there is formed a marsupium, or sort of pouch, connected with the lower surface of the thorax, into which the eggs are received and retained until the young escape. The greater number of the Cirrhipoda are hermaphrodite; but it has been shown by Goodsir, that this is not a universal characteristic of this class.

Among the different families of the large class *Insecta*, the arrangement of the generative organs presents great variety. The sexes are always distinct, and impregnation is invariably effected by copulation; hence, the external aperture of the efferent duct is found to be variously modified, according to the different circumstances in which the animal lives, and the modification of its general form. In some classes, the females are very few in number, and often whole colonies are developed from one female. This is the case amongst the bees, termites, and ants, in which the great

majority of the individuals are found to be neuters or workers. In the pupa of these last, the generative organs may be distinguished, but they afterwards become atrophied. Now it appears probable, that the development of the female organs is dependent upon nourishment; for it has been found, that the larvæ which are to become fertile females, or queen bees, have been supplied with a much more stimulating kind of food than that upon which the workers have been fed.

The generative organs are double and symmetrical in insects, and several accessory organs are found connected with the efferent duct. Of these, the most remarkable is a receptacle connected with the vagina of the female, designed to receive the seminal fluid of the male. This vesicle is termed the *receptaculum seminis*, and in it the spermatic particles of the male may be kept in a living condition for a very long period of time. The ova are impregnated as they pass the orifice of the duct of the receptaculum seminis. Besides this last, there is another organ connected with the lower part of the female genital organs, designed to receive the penis of the male. This is known as the *bursa copulatrix*, which, however, is not universally present. Mucous glands pour their secretion into the vagina near its external orifice.

The arrangement of the *ovaries* differs considerably in various classes. The gland usually consists of cæcal tubes, which are four or five in number, and open into the summit of the efferent duct; while in some the tubes open separately in the sides of the duct. The number of secreting tubes is very variable in the different classes.

The *testicles* consist of two or more (and often there are very many) simple cæcal tubes, the arrangement of which varies much, and which opens into the vas deferens of the corresponding side. The vasa deferentia are often very long and much convoluted; in some instances they are dilated below, so as to form a sort of vesicula seminalis.

The copulatory organs vary much in their disposition; usually they consist of hard, horny valvular appendages. In some species, suckers are developed upon the legs; and other arrangements are found for the purpose of retaining the female during the act.

The imperfect or larval form of many insects when they leave the egg, has already been alluded to under the heads of metamorphosis and metagenesis, or alternation of generations.

Vertebrata.

In the vertebrata, with the highest and most perfect development of the generative function, we shall find the progressive elevation characterized by greater complexity of structure, more protracted dependence of offspring on parent, and closer relations of the two sexes.

Fishes.—There are three types of structure in the generative organs of fishes. First, in the Cyclostomatous Group and in the Eel, the ovary consists of membranous folds depending from the spine, between the layers of which the ova are, at the spawning season, developed. When mature, they escape by the rupture of the membrane into the general peritoneal cavity, in which they may be found in large numbers, and from which they escape by a small opening situated near the anus. The male organs are to the unaided eye so like the female, that it is only in the spawning season that they can be distinguished: the spermatozoa escape into the peritoneal cavity in the same manner as the ova. Secondly, in the Osseous Fishes, the ovary, or *roe*, consists of a large membranous sac, inclosing the ovigerous folds, between the layers of which the ova are developed, just as in those we have described, so that when the ova escape they are discharged, not into the general peritoneal cavity, but into this ovarian sac, and thence find their way out by a tubular prolongation of it, or excretory duct, which opens just behind the anus. The testicle is strictly analogous. In neither of these classes does copulation take place; the spawn is cast abroad into the water, and left to be fecundated by the sperm discharged over it by the male, to be devoured, or to perish in an unfecundated state, as chance may direct. One of the most remarkable points in the history of osseous fishes is their immense fecundity: it is calculated that a Cod discharges nine millions of ova in a single spawning season. The reason of this unparalleled fertility appears to be, that there may be the greater chance of *some* escaping and surviving the many perils to which they are exposed. Thirdly, in the Cartilaginous Fishes, as the Sharks and Rays, we have a much higher type of the generative function. Copulation takes place; the male is furnished with an intromittent organ, and with certain accessory parts, called "claspers," for seizing and embracing the female during the act of impregnation. In the female, the ovaries are racemose, from the increased size and diminished number of the eggs, which, instead

of escaping into the peritoneal cavity, are seized by the patulous orifices of two long oviducts, whereby they are conveyed out of the body, and by which they are furnished with that peculiar horny shell, which serves at once to protect and to attach them to some fixed point.

Reptilia.—The *Amphibia* exhibit, in the function of generation, an interesting link between the piscine and the true reptilian structure; there is no intromittent organ, and yet copulation takes place, and the ova are fecundated neither after extrusion, as in the osseous fish, nor before extrusion, as in true reptiles, but during the very act of discharge, *in exitû*. At the commencement of the spawning season, a remarkable papillary structure is developed on the thumbs of the male frogs, highly sensitive, and giving rise, when stimulated, to a forcible reflex action, by which the upper extremities are approximated, and tightly embrace anything placed between them (p. 298.) By means of this, the male frog firmly embraces the female, and continues to do so through the whole time of the expulsion of ova, without any expenditure of voluntary action, and impregnates the ova as they pass from the female beneath him. The vas deferens passes through the structure of the kidney, and opens at once into the ureter, the two being thence continued as one duct—a sort of prolonged genito-urinary cloaca. In the *Triton*, we go a step further, and find the ureter and vas deferens distinct to their termination, and impregnation taking place internally, although there is no rudiment of a penis. The *Ophidians* present a further advance, and show the first trace of a penis; it consists of two erectile corpora cavernosa, which, however, are quite separate, and constitute rather an organ of prehension than of intromission. In the *Saurians* and *Chelonians* another step is gained, and the two corpora cavernosa are united in the middle line; there is still, however, no corpus spongiosum, and no prolongation of the urethra, but the seminal secretion passes into the female along the groove formed by the union of the two cavernous bodies.

Aves.—The generative organs of birds exhibit a close analogy to those of the higher reptiles, the penis is even less developed, except in the struthious birds (ostrich) and the swimmers. The ovary is racemose and single, the right with its oviduct being permanently atrophied: a singular violation of symmetry which is confined to birds. In this class of vertebrata, incubation, that singular substitute for utero-gestation, attains its highest perfection; it appears to arise from the concurrence of these three exigencies: the necessary size and early maturity of the young, the necessity of warmth to their development, and the incompatibility of utero-gestation with flight.

Mammalia.—It is from the possession of a remarkable accessory organ of generation that this important class of the highest organized beings takes its name. After all organic connection has ceased, the young are still dependent on the parent for nourishment, and are supported by the secretion from a special gland with which the female is furnished for the purpose—the mammary gland. The mammalia are divided into the *monotremata*, the *marsupialia*, and the *placental mammalia*. The monotremata are as yet imperfectly known, but they present a curious connecting link between the oviparous and mammalian type; they derive their name from possessing but one aperture, that of the cloaca, common to the generative, urinary, and digestive canals, and in this respect resemble birds; they are represented by the ornithorynchus and echidna of Australia. In the male, the penis is perforated by a urethral canal, through which the semen, but not the urine, passes; in the female, the ovaries are racemose, the ova large, and containing all the elements of an egg, and there are two uteri, opening by distinct apertures into the cloaca. The *marsupialia* (called so from the possession of a marsupium, or pouch, in which the young is lodged and suckled after its discharge from the uterus) are *ovo-viviparous*, that is, the young are brought forth alive, but they never have any placental connection with the parent. Not only are there two uteri, but two vaginæ, which terminate by two separate orifices in a sort of genito-urinary cloaca.* About thirty-nine days after conception, the young is expelled into the marsupium, where it becomes attached to one of the nipples by its mouth, and continues thus to draw nourishment from the mother for a period of eight months: this peculiar method of fœtal nourishment necessitates a very advanced and disproportionate development of the organs of assimilation, which is the most remarkable characteristic of the embryo marsupial. The *placental mammalia*, in the general structure of their generative organs, resemble man. The testicle consists of seminiferous

* In the male, the testicles are contained in a scrotum placed above, and not below the penis, in a situation analogous to the marsupium in the female, and supported, like it, by two marsupial bones: the vasa deferentia open into the urethra, which, invested by its corpus spongiosum, passes through the centre of the penis, and which now, for the first time, we find forming a complete canal, leading from the bladder to the extremity of the intromittent organ.

tubules arranged in bundles, and inclosed in a fibrous capsule. The penis is composed of two corpora cavernosa arising from the ischia, a corpus spongiosum urethræ, and glans; and there are certain accessory glandular structures, vesiculæ seminales, prostate, and Cowper's glands, opening into the urethra in its course. Into the different numbers, modification, and structure of these organs it is not worth while to enter. In the rabbit, the ovary exhibits some trace of the racemose structure, and, by the different modifications of the uterus, dependent on the proportionate size of its body and cornua, we are conducted from the marsupialia, in which the two uteri are entirely distinct, to the human female, in which the single uterus exists in its greatest degree of concentration.

In writing the present chapter, the authors have received much assistance from the following works: Müller's "Elements of Physiology," by Baly; Professor Owen's Lectures "On Comparative Anatomy," and his treatise "On Parthenogenesis;" Dr. Carpenter's "Principles of General and Comparative Physiology;" Victor Carus' "System der Thierischen Morphologie;" Art. Ovum, in the "Cyclopædia of Anatomy and Physiology," by Dr. Allen Thompson; "On the Alternation of Generations," by Professor Steenstrup, translated by the Ray Society.

CHAPTER XXXVII.

MALE ORGANS OF GENERATION.—TESTICLES.—VASA DEFERENTIA.—VESICULÆ SEMINALES.—PROSTATE GLAND.—COWPER'S GLANDS.—PENIS.—URETHRA.—GLANDS OF LITTRE.—GLANDULÆ TYSONI.—VESICULA PROSTATICA.—SEMINAL TUBULES.—SPERMATOZOA.—DEVELOPMENT OF SPERMATOZOA.—MOVEMENTS OF SPERMATOZOA.

Male Organs of Generation.—The essential organ of generation, or the secreting portion of the sexual apparatus, in the male, is the testicle. The efferent duct is the vas deferens, which opens into the membranous portion of the urethra, and connected with it are the vesiculæ seminales and Cowper's glands. The urethra is continued forwards along the lower part of the penis, or *intromittent* organ.

Testicles.—Each testicle is rather less than two inches in length. and is nearly one inch broad.—Its weight is about six drachms. The testicle is covered by a firm, fibrous, inelastic tunic, or proper covering, the *tunica albuginea* or *tunica propria*, consisting almost entirely of white fibrous tissue, in the substance of which vessels ramify. It is with difficulty divided into two layers, the inner of which is the most vascular. Adhering closely to the tunica albuginea, is the visceral layer of the serous membrane, or *tunica vaginalis*, the sac of which was originally formed by the descent of the testicle from the abdomen, when it carries before it a process of peritoneum. In early life, the cavities of the tunica vaginalis and peritoneum are continuous with each other; and, occasionally, the opening remains unclosed in the adult. The parietal layer of the tunica vaginalis is loose, and united by lax areolar tissue to the other structures which form the scrotum. This layer of the serous membrane admits of considerable distension; and, in disease, a very large quantity of serous fluid will sometimes accumulate in the sac, and distend it to a great extent (*hydrocele*).

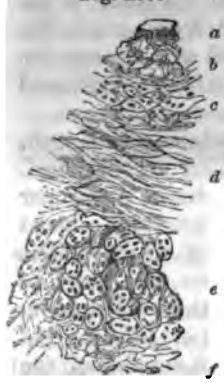
Structure of the Gland.—The secreting portion of the organ consists of a vast number of a minute and highly tortuous tubes, which are arranged in conical lobes, or parcels, each consisting of two or more tubes, which are covered with a layer of condensed areolar tissue, continuous with the *corpus Highmori.* These divisions are, however, not complete; for the tubes of one parcel communicate with those of the adjoining ones. The highly convoluted seminal tubes commence in blind extremities or in loops; and, after dividing fre-

Fig. 256.

a. Origin in blind extremities and branching of seminal tubules—human subject. *b.* One of the blind extremities more highly magnified.

quently, and forming anastomoses, they become less tortuous as they approach the mediastinum testis, where two or more unite to form a short straight duct, the *vas rectum;* these vasa recta again unite, so as to form a sort of network, the *rete testis,* which occupies the *mediastinum testis* or corpus Highmori. From the rete testis pass the *vasa efferentia,* which are usually about twelve or sixteen in number, and are much convoluted; and, by being packed together, form part of the epididymis. They open into a single and highly tortuous duct, the *vas deferens,* which is usually about sixteen inches in length, and forms a very hard, round efferent duct, readily distinguished, by the feel, from the other structures which compose the spermatic cord. The vas deferens is lined with a single layer of tesselated epithelium, and there is a layer of very lax areolar tissue beneath the mucous membrane, which would permit of great increase in the diameter of the canal when it was distended with secretion, *b,* fig. 257. It passes behind the bladder, and terminates in one of the *ejaculatory canals,* a very short canal, which is formed by the union of the vas deferens with the corresponding *vesicula seminalis,* which is situated a little external to it, upon the posterior surface of the bladder.

Fig. 257.



Transverse section of the vas deferens—a segment only is represented in the drawing. *a.* Lining membrane of the tube connected by a thick layer of lax submucous areolar tissue (*b*) to a thin longitudinal layer of unstriped muscle (*c*). *d.* Layer of circular or transverse fibres. *e.* External thick layer of longitudinal fibres, surrounded by an outer covering of areolar tissue, *f.* From a drawing by Dr. Beale.

æ Seminales.—The vesiculæ seminales are two sacculated ı, about two inches in length and about three-quarters of breadth, situated upon the posterior aspect of the bladder, een it and the rectum. They converge towards the point hey open, and almost meet. The narrow terminal portion for a short distance, previous to its opening in the urethra, l by the prostate. Each vesicula may be unravelled, so as :æcal tube, with several diverticula projecting from it. It ch convoluted, and the convolutions are connected together ır tissue, to which arrangement the sacculated appearance

Fig. 258.

Vesicula seminalis, after E. H. Weber. *a.* Ejaculatory duct. *b.* Vas deferens. *c.* Vesicula seminalis. *d.* Terminal diverticula.

ıcture of the vesiculæ seminales is ar to that of the vasa deferentia, walls are much thinner. There is :oat, composed of areolar tissue, in erous muscular fibre-cells are found. ined with a thin layer of tesselated .

iculæ are usually found to contain a .cus-like substance, which may be ıs their secretion; and which, no of a nature favourable to maintain activity of the spermatozoa, and to dilute the semen. These organs erly looked upon as the receptacles :men; but a comparison of their nt, and an examination of their n the lower vertebrata, by no means his view, as our friend, Mr. Pittard, ked. In the elephant, the vesiculæ open into the vasa deferentia, as in seminal reservoirs are also found in ıl. In man, however, spermatozoa generally found in them; and it is hat they serve partly as receptacles nen, but at the same time, there can ɔt that they furnish a proper secretion of their own for its nd for the preservation of its integrity.

e Gland.—The prostate may be described as consisting of two distinct structures; first, of a glandular portion, of conical or roundish vesicles lined with cylindrical and containing brown granules; and, secondly, of several fibrous tissue, with which many fibres of unstriped muscle rhere incorporated; indeed, the proportion of the muscular ıs elements to the glandular structure, is so great that alculates that the latter does not constitute more than one- of the whole mass of the gland. The muscular fibres he prostate, were originally described by Mr. Hancock. :reting follicles open into ducts, which are lined with

cylindrical epithelium, presenting similar characters to that found in the prostatic portion of the urethra.

The ducts, which are very numerous, open into the urethra, upon each side of the *caput gallinaginis.*

Little is known with reference to the nature of the secretion of the prostate, or of the function which it performs. The secretion is stated to be very similar in character to that of the vesiculæ seminales.

Small concretions, or prostatic calculi, are very frequently met with in the follicles of the gland, or are voided during life. They usually consist of phosphate of lime, with animal matter, and a trace of carbonate of lime; and are often remarkable for their perfectly spherical form and smooth glistening surface. They commence by the deposition of calcareous matter in the walls of large oval cells, which are, probably, altered epithelial cells of the gland itself. Dr. Handfield Jones has carefully investigated the formation of prostatic concretions.*

Cowper's Glands.—These small glands are two in number, and are situated anterior to the prostate, between the layers of the triangular ligament. Their somewhat long excretory ducts open into the bulbous portion of the urethra. They are composed of vesicles, lined with tesselated epithelium, which pour their secretion into ducts lined with columnar epithelial cells. As in the case of the prostate, the secreting portion of these little glands is imbedded in a fibrous stroma, which contains very numerous unstriped muscular fibre-cells. The secretion of these glands appears to be analogous to ordinary mucus.

Penis.—The penis of man is a highly vascular organ, traversed on its inferior surface by the urethra; it is composed principally of erectile tissue, which is capable of being distended with blood. This erectile tissue is arranged in three distinct divisions termed the *corpora cavernosa* and *corpus spongiosum.* The corpora cavernosa penis are two in number, and are separated from each other, posteriorly, by a septum, composed of fibrous tissue; while anteriorly, they are connected together, and might be considered as one organ. In the middle line above, is situated the dorsal vein, and other vessels and nerves; while the corpus spongiosum urethræ is received into a groove beneath. In the posterior part of the organ, the corpora cavernosa are separated from each other by a considerable interval, and each is inserted into the rami of the ischium and pubis; these two diverging extremities of the corpora spongiosa are termed the *crura* of the penis.

The corpora cavernosa are invested with a layer of firm fibrous tissue, which contains numerous fibres of the yellow elastic element.

The *corpus spongiosum urethræ* surrounds the urethra, and commences behind, in a dilated portion situated between the crura penis; and it terminates anteriorly in the expanded *glans penis,* the rounded

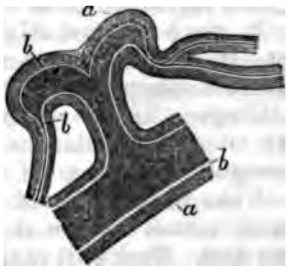
* Medical Gazette, Aug. 20th, 1847.

margin of which is termed *corona glandis*, and the constricted part beneath, the *cervix* or neck.

These bodies consist of a vast number of small venous sinuses, which communicate with each other upon all sides, and contain venous blood. The walls of the sinuses or *trabeculæ* are lined with a layer of tesselated epithelium, external to which is found the proper fibrous tissue, or *trabecular tissue*. This is composed of white and yellow fibrous tissue, and fibres of organic muscle. The arteries and nerves for the supply of the organ are supported and surrounded by this texture.

The *arteries of the penis* are branches of the pudic; and in their arrangement, present certain peculiarities, which are well worthy of notice. The smaller divisions, after pursuing a tortuous course in the trabecular tissue, at length open into the venous sinuses, without entering into the formation of any capillary plexus. In the posterior part of the penis, J. Müller discovered several minute arteries, which were much convoluted, and assumed the twisted appearance of tendrils; whence they were termed the *helicine arteries*. Kölliker has shown that these arteries terminate in minute vessels, and not in blind extremities, as was originally supposed; the minute terminal vessels ultimately open into the venous spaces. The arrangement of the arteries in the corpus spongiosum urethræ, is similar to that just described.

Fig 259.



A small artery of the corpora cavernosa, giving off a lateral branch, from which proceed helicine arteries, terminating in very small vessels, which are continued in the trabecular tissue, (a.) b. Wall of the arteries. After Kölliker.

Urethra.—The male urethra is the canal which extends from the neck of the bladder to the end of the penis. It is about eight inches and a half in length, but varies slightly in different cases. The tube itself is lined with mucous membrane, and its diameter is not by any means the same in its whole extent. Its direction is that of a double curve, like the letter *f*. The walls of the urethra are strong, and composed principally of fibrous tissue, with a layer of unstriped muscular fibre, the arrangement of which has been well described by Mr. Hancock.

The urethra is divided, by descriptive anatomists, into three portions; the *prostatic*, being about twelve lines long; the *membranous*, about three-quarters of an inch in length in its upper part, but only half an inch in its lower portion; and the remainder, by far the most extensive portion of the canal, called the *spongy portion*, which reaches to the orifice.

The *prostatic portion* of the urethra is its widest part, and lies imbedded in the upper part of the prostate, above its middle lobe.

At the neck of the bladder, the mucous membrane forms a fold, called the *uvula vesicæ*. Anterior to this is a narrow ridge, rising from the floor of the tube, about nine lines in length, and about one

and a half lines in height in its highest part, called the *verumontanum, caput gallinaginis*, or *crest of the urethra.** On each side of this, the mucous membrane forms a depression, the prostatic sinus, into which the ducts of the prostate gland open.

At the highest part of the *verumontanum* is a little sinus, the *vesicula prostatica*. It is here that the ejaculatory ducts open.

The *membranous portion* is that narrowest part of the urethra which lies beneath the pubis and passes through the layers of the triangular ligament. It is surrounded with muscular fibres, and the *compressor urethræ* muscle is situated upon this part of the tube; beneath it are Cowper's glands. This part of the urethra commences at the anterior extremity of the prostate, and terminates in the bulbous portion. Its upper surface is rather longer than the lower one, and it curves upwards.

In the evacuation of the bladder, it is most likely that the compressor urethræ muscle, which contains striped fibre, and guards the membranous portion of the urethra, becomes relaxed; then follows the relaxation of the sphincter vesicæ, and the contraction of the fibres of the bladder (detrusor urinæ), which causes the urine to escape from the urethra with considerable force.

The *spongy portion* of the urethra is about six inches in length, and is so called, because it is surrounded by the corpus spongiosum urethræ. That part of the canal in the bulb is somewhat dilated, but the diameter of the greater part of this portion of the canal is uniform. Cowper's glands open near the anterior extremity of the *bulbous portion*. When it reaches the *glans*, however, it undergoes another dilatation, the *fossa navicularis*. At its orifice, the urethra is contracted.

Mucous Membrane.—The short papillæ covering the *glans* become much elongated at the orifice of the urethra, and highly vascular papillæ are found in the anterior half of the fossa navicularis (fossa Morgagnii). They then cease abruptly, but recommence in the posterior part of the glans, and are continued as far as the bulbous portion.

About one-third of an inch from the meatus, on the dorsal aspect of the fossa navicularis, is situated the *lacuna magna*. In other parts of the mucous membrane of the urethra, except in the prostatic portion, are numerous small lacunæ.

Glands of Littre.—The majority of these are simple involutions of the mucous membrane, or lacunæ; but some may be described as small branched glands or follicles, which are numerous in the cavernous portion of the urethra. These become more simple in the prostatic portion, and take the form of simple follicles.

The epithelium lining the urethra and the small glands just referred to, is for the most part of the columnar form.

Glandulæ Tysonianæ.—These little glands are situated in the fold of skin round the glans penis. They are modified sebaceous

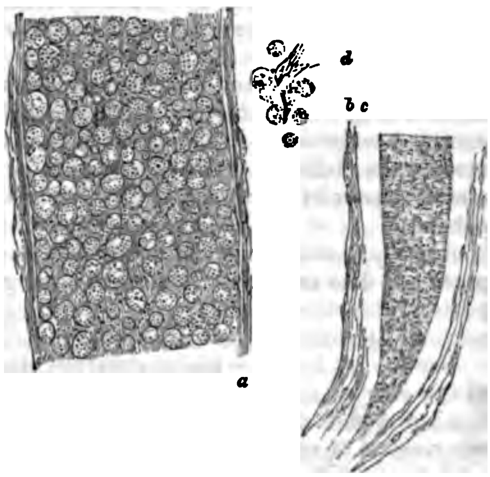
* Vide article "Vesicula Prostatica," in the Cyclopædia of Anatomy and Physiology, by Prof. Rud. Leuckart.

glands, and the follicles of which they are composed contain epithelium and fatty matter, resembling that which is met with in the ordinary sebaceous follicles of the skin. In this locality these glands open upon the soft skin of the prepuce, and are not associated with hair follicles, as is usual in other situations in which they are found. The peculiar secretion known as the *smegma preputii*, is not due to these glands alone; but is rather to be regarded as an accumulation of the moist epithelium of the glans, which is, of course, mixed with the odoriferous sebaceous material. In the beaver, the epithelial secretion is so abundant, as to accumulate in large preputial pouches, the true nature of which was demonstrated by E. H. Weber. The secretion constitutes the substance known as castor.

Vesicula Prostatica.—Between the openings of the *ejaculatory ducts* in the middle line of the urethra, and in the substance of the *caput gallinaginis*, is a samll cavity, lined with columnar epithelium, the *prostatic vesicle*, or *uterus masculinus*, as it has been termed by Weber, from its supposed homology with the female organ. It has since been described under the name of Weberian organ, from its discoverer.

Seminal Tubules.—The highly tortuous seminal tubes, of which the true secreting portion of the testicle is composed, consist of a fibrous coat, internal to which we find a basement membrane surmounted by epithelium. Now the characters of this epithelium, and the nature of the contents of the tube, will be found to exhibit different appearances, according to the age of the individual; and in the lower animals, according to the period of the year. Spermatozoa, which are the fertilizing agents, are not found before puberty in man, and among animals are only developed at certain periods. These bodies appear to be formed by certain alterations taking place in the character of the epithelium lining the tubes, for this latter is most distinct when spermatozoa are not being formed; but when the function of the gland is very actively performed, the tubes are seen to be entirely occupied by cells, in which the spermatozoa are ultimately developed.

Fig. 260.



Portion of seminal tubules of man, with enclosed cells. Magnified 220 diameters. *a.* Wall of the tube. *b.* Nuclei of fibrous coat. c. Basement membrane.—The latter figure represents the action of acetic acid. *d.* Cells removed from the tubule.

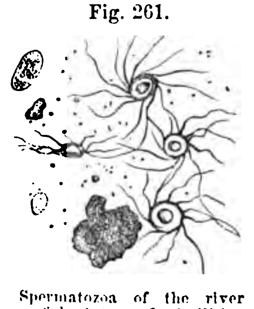
When semen is about to be formed, the following changes may be observed to take place in the epithelium.

The cells become detached from the basement membrane, increase in size, and assume a more spherical form, the contents at this time being entirely granular; at length, however, several clearer points or nuclei are seen in the interior of the cell, which is now passing down the tubule towards the vas deferens, while it is succeeded behind by the formation of new cells. The nuclei in the interior enlarge, and are often seen to contain nucleoli. The parent cell, having much increased in size from the development of its nuclei into cells, appears to undergo no further change; but in each of the contained cells, which vary much in number, one spermatozoon is developed on the inner wall, in the form of a spiral filament, as was first described by Kölliker. The spermatozoon escapes into the interior of the mother cell by the rupture of its development cell. Others are in like manner set free; and they arrange themselves in a parcel, which may ultimately consist of a vast number of separate spermatozoa, with all the heads arranged in one direction and the tails in the opposite one.

The cause of this arrangement is probably somewhat similar to that which determines the blood discs to run together, and assume the form of a small pile of coins. There appears to be a sort of attraction existing between the different spermatic filaments for each other. The contained spermatozoa are at last set free by the rupture of the parent cell, and then separate. These changes are usually not completed until the cells arrive at the epididymis; so that in the seminal tubules cells alone are found, while in the vas deferens we only meet with perfectly developed spermatozoa.

Spermatozoa.—The spermatic filament or spermatozoon of man is a perfectly clear hyaloid filamentous body, in which a dilated portion, termed the *body* or *head*, may be observed, from which is prolonged a long *tail* or *filament*, which gradually tapers to an extremity which is hardly visible from its extreme tenuity. The head or larger extremity is flattened from side to side and of a conical form, the pointed extremity being anterior. The length of the spermatozoon is about $\frac{1}{800}$th of an inch, and the width of the body in one direction about the $\frac{1}{5000}$th, and not more than the $\frac{1}{10000}$th of an inch in the opposite. The tail varies somewhat in length in different specimens.

Fig. 261.



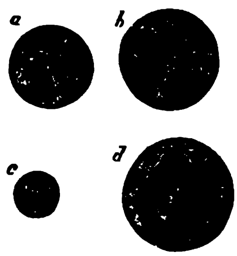
Spermatozoa of the river crawfish (Astacus fluviatilis).

The characters of the spermatozoa vary much in different animals; thus, in the rat and mouse, the head or body is unsymmetrical and curved. In the squirrel, the anterior extremity of the head is rounded, and wider than any other portion. In birds, the head is usually attenuated. In reptiles and fishes, the characters of the spermatozoa vary much in different examples. Among the invertebrata, those of the crustacea are very remarkable in form. For a detailed account of the characters of the spermatozoa in different classes of animals, we must refer the reader to the excellent article, Semen, in the *Cyclopædia of Anatomy and Physiology*, by Wagner and Leuckart.

Development of the Spermatozoa.—The development of the spermatozoa has been carefully investigated by Wagner, Siebold, and Kölliker. The different stages are traced more readily in many of

the lower animals than in man. In the rabbit, Kölliker has been able to observe the single spermatic filament within the cell attached to the wall and making two or three turns in a spiral form. It may now be looked upon as almost certain, that each spermatozoon is developed not from any change of the cell, but from the contents within the cell itself. These cells are themselves developed in the interior of a larger or *mother* cell, into the interior of which the spermatozoa escape by the rupture of their developing cells, and are at last set free by the destruction of the wall of the parent cell itself. Professor Kölliker, in his latest investigations, has arrived at the conclusion that the spermatozoa are not developed *in* the nuclei of the cells, but *from* them. The nucleus becomes of an oval form, and one extremity is elongated to form the filamentary tail, while its principal part constitutes the body of the filament. In this case, they arrange themselves parallel to each other, the heads being in one direction, and the tails in the opposite.

Fig. 262.



Development of the spermatic filaments of the rabbit. *a.* Parent cell, with five nuclei. *b.* Each nucleus of the parent cell containing a spermatic filament. *c.* Nucleus with spermatic filament. *d.* A parent cell, with a number of spermatic filaments set free from the nuclei or cells of development.

Movements of the Spermatic Filaments.—When the spermatozoa have escaped, their active movements commence; and by the continual vibrations of the filamentous tail, they are propelled forwards, according to Henle, at the rate of one inch in seven minutes and a half. The tail alone possesses the power of movement, and the force of the motion is sufficient to move objects many times the weight of the spermatozoon.

The movements are stopped by all those solutions which act chemically upon the spermatic particle. In water, the activity of the movements is at first increased, but it soon stops altogether, probably in consequence of endosmosis. Urine very soon puts a stop to the movements. The electric spark instantly stops the motions; but, according to Prevost, galvanism exerts no action upon them.

After spermatozoa have become quite motionless, and appear to be dead, movements may be excited by the addition of concentrated solutions of different substances, such as sugar, albumen, urea, and various salts. Caustic alkalies in various degrees of concentration, from $\frac{1}{30}$ to $\frac{6}{10}$, are special excitants of the movements. Moreover, Kölliker states that semen dried in indifferent substances and in saline solutions, in certain cases, may have its motion restored by dilution with the same fluid or with water. The motions cease in a high or low temperature.

In the interior of the female organs of generation, the movements continue for a longer period than in any other situation. In the receptacula seminis of insects, spermatozoa have been known to retain their power of movement for many months after they had been discharged by the male, and in the higher mammalia, the movement

54

continues in the mucus lining the generative organs of the female for many days after copulation.

It must be borne in mind that the semen does not consist only of the secretion of the testicle, but that it also contains the secretions of the prostate, vesiculæ seminales, and Cowper's glands. What purposes these different secretions serve, it is difficult to say, but it is probable that they merely effect the dilution of the fluid in which the spermatozoa move, and thus render it a more favourable medium for their diffusion.

The movements of the spermatozoa have been regarded by some as due simply to the existence of endosmotic currents, while other authorities have attributed them rather to the inherent contractile property of the tissue of which they are composed.

The action of certain saline solutions upon these movements, does not seem, to us, to place this question in a much clearer point of view: since the mere physical alteration occurring in their contents would alone be sufficient to excite the contraction of the tissue of the spermatozoon.

That the spermatozoon is really the essential part of the semen, and is that in which all the mysterious fecundating power resides, may be now looked upon as proved beyond a doubt. The later beautiful observations upon the ova of the frog, of our lamented friend, Mr. Newport, have shown that impregnation does not take place unless the spermatozoon actually passes through the vitelline membrane and comes into immediate contact with the yolk substance.

The chemical analysis of the semen has not led to any very important results. The investigations of Frerichs are some of the latest that have been undertaken upon this subject. The most important fact which he has established is, that the spermatozoa consists of binoxide of protein, the substance of which epithelial cells are chiefly composed. The other constituents of semen are phosphate of lime, fatty matter, a certain quantity of extractive matter with alkaline sulphates and phosphates, and a small quantity of phosphorus in an unoxidized state. The imperfectly developed semen contains albumen, but this substance cannot be detected in the fully formed secretion.

From the various phenomena which we have been considering, and from many other facts which might have been brought forward, we are led to conclude that the spermatozoon is to be regarded in the light of an epithelial cell, or, rather, its nucleus, modified in structure and endowed with peculiar properties. Its mode of development, the continuous and obviously involuntary nature of the movements, and lastly, its chemical characters, all tend to this conclusion, while they place the originally received notion of the animal nature of the spermatozoon without the bounds of speculation.

Upon the nature of the force which is communicated by the spermatozoon to the ovum, we know nothing. Whether it is to be looked upon as a catalytic action, or whether the changes induced are of a chemical nature, are questions to which we can give no answer.

Certain it is, that the integrity of the spermatozoon is necessary for fecundation. The spermatozoa of hybrids have been found, upon examination, to exhibit structural imperfections, and it has long been known that these animals are incapable of producing offspring.

That all the wonderful changes taking place in the ovum, which lead to the formation of the embryo and the development of the new being, result from the agency of the spermatozoon, is certain; but *how* these are brought about, seems beyond the pale of human knowledge.

Upon the subjects treated of in the present chapter, the student may refer to Sir Astley Cooper's "Observations on the Structure and Diseases of the Testis;" Lauth's "Mémoire sur la Testicule Humaine;" Professor Kölliker's Microscopic Anatomy, and articles in the "Microscopical Journal;" Hancock, "On the Physiology of the Male Urethra;" Article "Semen," in the "Cyclopædia of Anatomy and Physiology."

CHAPTER XXXVIII.

FEMALE ORGANS OF GENERATION.—OVARIES.—GRAAFIAN FOLLICLES.—GERMINAL VESICLE.—PAROVARIUM.—FALLOPIAN TUBE.—UTERUS.—VAGINA, AND ACCESSORY ORGANS OF GENERATION IN THE FEMALE.—FEMALE URETHRA.

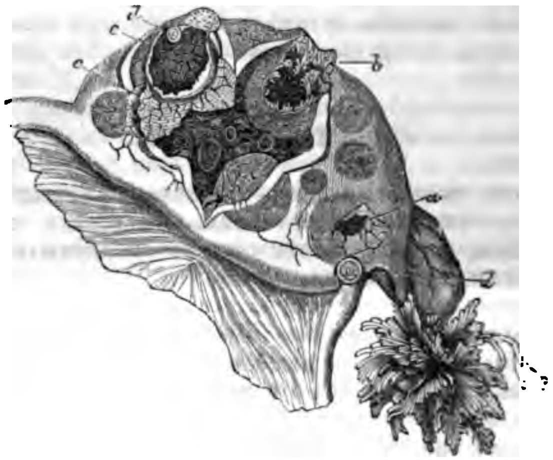
Female Organs of Generation.—The formative organ in the female is the *ovary*, in which the *ova* are developed and prepared for fecundation. From the ovary, the ova pass into the *Fallopian tube* or efferent duct, which opens into the *uterus*, the cavity designed for the reception of the ovum after it has been impregnated, in which the formation of the embryo takes place, and its development into the form of the future being occurs. From the uterus passes the *vagina* or tube which receives the penis of the male in copulation. With the vagina are connected certain glands and accessory organs.

Ovaries.—The ovaries are two in number, of an oval form, and flattened antero-posteriorly; they lie in the cavity of the pelvis, and are enclosed in a fold of the broad ligament of the uterus, with which organ they are connected by a narrow cord or *round ligament.* Each ovary is invested with a firm capsule of condensed fibrous tissue, which is covered with peritoneum, and is usually attached to the corresponding Fallopian tube by one of the fimbriæ of the latter. The ovary is composed of a firm, fibrous, and highly vascular stroma; in which are imbedded, at various intervals, a number of small cavities or vesicles, originally discovered by De Graaf, hence called *Graafian vesicles.* These contain a serous fluid, with a considerable number of cells, amongst which the ovum lies. In the adult ovary, there are usually from ten to fifty, or more, of these Graafian vesicles, varying in size from a small pin's head to that of a pea. The largest are situated chiefly towards the peripheral part of the organ. In

the ovary of the advanced fœtus and new-born child, Graafian follicles are abundant, and, even at this early period, the ovum can be seen within them. The fibrous stroma of the ovary is exceedingly firm and hard; it consists principally of a modification of white fibrous tissue, the fibres of which interlace in all directions; but it is highly vascular, especially at the period of puberty.

Graafian Follicles.—The *Graafian follicles* or *ovisacs* consist, when fully developed, of a closed cavity and contents. The walls are composed externally of a firm fibrous membrane, which is connected with the fibrous structure of the ovary; internal to which is a softer and more spongy tissue, containing numerous fusiform cells and fibres, more loosely arranged than in the external part of the

Fig. 263.

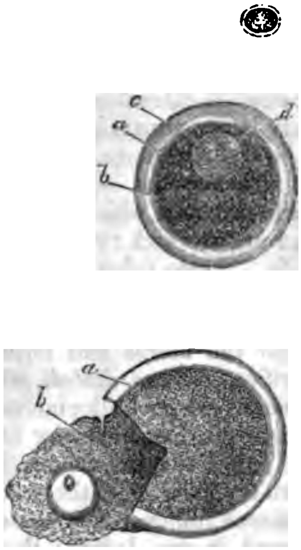


Ovary of human subject. *a.* Graafian follicle with opening. *b.* Inner lining of Graafian follicle or membrana granulosa. *c.* Outer portion of the same. *d.* Ovum. *e.* Vascular wall of tube. After Coste.

follicle. Internal to this, especially in young follicles, a clear hyaloid basement membrane may be observed, upon the surface of which, lining the entire follicle, is a tolerably thick layer of epithelium, the *membrana granulosa* of authors. The epithelium is much more abundant in that part of the follicle in which the ovum is situated: indeed, it is entirely imbedded in it. According to the observations of Dr. Barry, the ovum is attached to the walls of the follicle by certain bands, termed by him *retinacula*. It is, however, not easy to demonstrate satisfactorily this peculiar arrangement of the membrana granulosa. The cells of the membrana granulosa of the Graafian follicle have a polygonal form, and immediately around the ovum are collected into a sort of ring, which is attached to the external clear membrane, or *zona pellucida*, of the ovum. This layer is termed by Dr. Barry the *tunica granulosa*. The so called retinacula are composed of similar cells, of which many are also found floating in the fluid of the follicle, which is entirely lined by them.

Ovum.—The ovum is invested with a clear, homogeneous, perfectly transparent, firm, elastic, and tolerably thick membrane, exhibiting an appearance, when examined by the microscope, very similar to that of the elastic laminæ of the cornea, the *vitelline* or *yolk membrane*, or *zona pellucida;* the latter being the term always employed in speaking of the mammalian ovum. The zona pellucida appears as a perfectly clear ring, limited on either side by a well defined dark outline. Within this membrane is the yolk, which is composed of a fluid containing proper *yolk granules* and oil particles, with the clear bright *germinal vesicle*, containing within it the *germinal spot*, lying close beneath the zona pellucida.

Fig. 264.

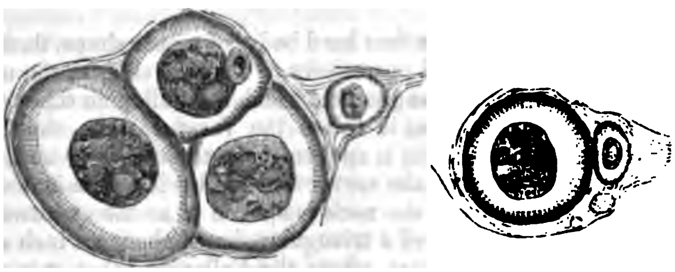


Mammalian ova. The upper figure shows an ovum at an early stage of development. The second figure, a mature ovum. *a.* Zona pellucida. *b.* Yolk. *c.* Germinal vesicle. *d.* Germinal spot. The lower figure shows the zona pellucida *a*, ruptured, and the escape of the yolk granules (*b*) and germinal vesicle through the opening. From Coste.

The ovum is about $\frac{1}{120}$th and the germinal spot about $\frac{1}{1000}$th to $\frac{1}{800}$th of an inch in diameter.

The yolk granules differ much in size and form in different animals. They are much more numerous in mature ova than in ova at an early stage of development, as was pointed out by Bischoff, an observation which we can fully confirm. They appear to be composed of a protein compound, with much fatty matter.

Fig. 265.



Ova in various stages of development, from the toad's ovary. In the right figure some very small ones are observed.

Germinal Vesicle.—The germinal vesicle, or vesicle of Purkinje, consists of a perfectly clear cell, filled with transparent contents, but containing one dark spot, the *germinal spot*.

From some observations of Kölliker and Bagge upon the development of the ova of intestinal worms, it appears that the germinal spot is the part of the ovum which is first formed; but it may be regarded as a fact, that the germinal vesicle precedes the formation

of the yolk and the zona pellucida. The immediate *formative organ* of the ovum is the Graafian vesicle.

As the ovum approaches maturity, it passes from the centre of the Graafian follicle towards its peripheral portion, and becomes imbedded in the membrana granulosa, which increases in thickness until it entirely surrounds the ovum. At the same time, the zona pellucida increases in thickness, and the germinal vesicle, which was originally situated in the centre of the yolk, makes its way towards the circumference.

Parovarium.—Diverging from the hilus of the ovary, may be seen a few canals, which appear to be the remains of the Wolffian body, an organ which reaches its maximum of development in intra-uterine life. These tubes have been termed the *parovarium.*

Fallopian Tube.—The Fallopian tube, or *oviduct*, is a fibro-muscular canal, lined with ciliated epithelium, opening by one extremity into the uterus and terminating in the other by a wide fimbriated orifice, *morsus diaboli*, which opens into the cavity of the peritoneum. Each Fallopian tube is usually, however, connected to the corresponding ovary by one of its fimbriæ.

The Fallopian tube is invested with peritoneum, and at the fimbriated extremity, the serous membrane becomes continuous with its mucous lining. The muscular fibres of the Fallopian tube are disposed in two layers; the external having a longitudinal and the more internal a circular course. The contractile fibres are mixed with much fibrous tissue. The contraction of the oviduct has a vermicular character. The mucous membrane is disposed in longitudinal folds, upon which lies a single layer of columnar epithelium. These cells are ciliated, and by the vibration of the cilia, a current is produced, the direction of which is from the ovaries towards the uterus; so that the transmission of the ovum into the uterus would be favoured, while the passage of the spermatozoa along the tube would be retarded.

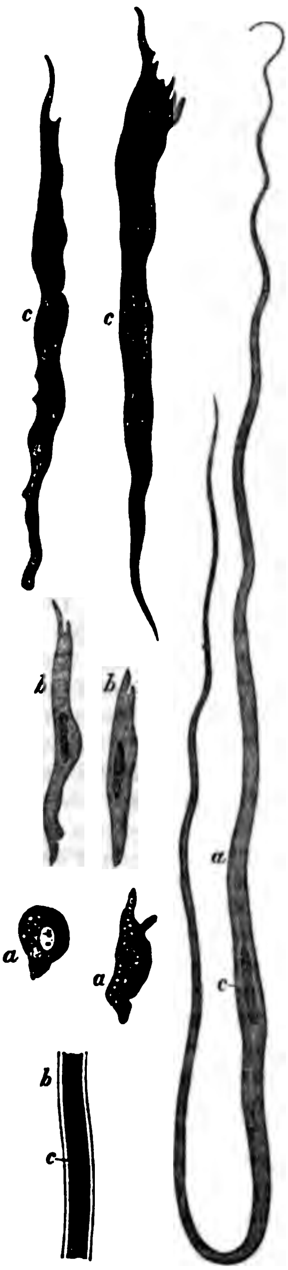
Uterus.—The uterus is a firm hard body, of a pear shape, flattened more or less anteriorly and posteriorly. On each side, at the upper part, are situated the two angles into which the Fallopian tubes open. The portion above this point is called the *fundus*, while the lower constricted part of the organ is spoken of as the *cervix* or neck, and that part situated between the cervix and fundus is denominated the *body*. The highest part of the neck is spoken of as the *os internum*. The cavity of the uterus is of a triangular shape, about an inch and a half in width at its upper part, where the Fallopian tubes open; but in the unimpregnated state, its walls almost touch each other, so as to leave a very slight interval, which is usually occupied by mucus. The cavity terminates in the *os uteri*, or *os tincæ*, a transverse opening, bounded anteriorly and posteriorly by two thick and rounded lips.

The uterus undergoes extraordinary alterations in form and size after the impregnation of the ovum, and becomes very vascular and endowed with a highly contractile power.

The walls of the unimpregnated uterus are about half an inch in

thickness in their thickest part, and consist of pale organic muscular fibres, with a certain quantity of fibrous and areolar tissue. The muscular fibres have been said to be arranged in three layers, but the limits of these layers are not very clearly defined. The outermost layer is very thin, and is incorporated with the sub-peritoneal tissue. It consists of longitudinal and transverse fibres, many of the latter, after investing the anterior and posterior surfaces of the organ, lose themselves upon the Fallopian tubes, or enter the broad and round ligaments. The middle layer makes up the greater part of the thickness of the uterine walls, and consists of strong bundles; which also run, some in a longitudinal and others in a transverse direction. It is in this layer that the greater number of the vessels which supply the organ, and which become so enormously developed in pregnancy, ramify. The innermost layer is thinner, and composed chiefly of thin longitudinal fibres.

Fig. 266.



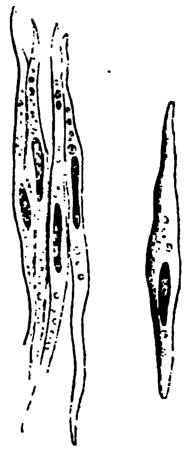
Muscular fibre cells, from a gravid uterus, in different stages of development. *a.* Formative cells. *b* and *c.* Cells at an advanced stage, from a uterus at the fifth month. The long cell is taken from another uterus at the sixth month. *c.* Its nucleus. After Kölliker.

Round the external os uteri, the transverse fibres are very abundant, and collected together beneath the mucous membrane, so as to form a sphincter muscle.

In these different layers, in the virgin uterus, the muscular fibre-cells for the most part are seen as short spindle-shaped cells, in many of which, oval elongated nuclei can be demonstrated. At this period, the cells are often seen to be of very irregular form, and are not always very readily made out. The muscular fibre-cells undergo increased development in the pregnant state, and towards the end of this period, will be found to be very long cells with a distinct oval nucleus. The cell terminates in long thin and pointed extremities (fig. 266). After delivery, these cells again diminish in dimensions, a number of fat

globules appear in their interior, and ultimately they regain their former appearance (fig. 267); while, at the same time, the entire organ returns to its former volume.

Fig. 267.



Muscular fibre cells from the uterus, three weeks after parturition, showing the fat globules in their interior. The four cells to the left have been treated with acetic acid. After Kölliker.

The mucous membrane of the uterus forms a pale and not very thick lining membrane. In the fundus and body of the organ, it is of a redder colour than in the cervix, in consequence of the greater vascularity of this part.

The epithelium is of the ciliated variety.

Imbedded in the mucous membrane of the uterus are numerous glandular follicles, much resembling the follicles of Lieberkühn, in the intestine. These follicles are lined with cylindrical epithelium. They appear to form a little whitish mucous secretion. In pregnancy, these glands are enormously developed; and we shall consider the changes taking place in their structure, when describing the alteration which takes place in the mucous membrane of the uterus after conception. The mucous membrane of the cervix uteri is gathered into deep folds, forming *rugæ*, between which are seen secondary rugæ, with a few follicles opening between them. These rugæ were described by the older anatomists, under the terms *plicæ palmatæ*, *arbor vitæ uterinus*, etc.

In the mucous membrane of the neck of the uterus, are situated the so called *glandulæ*, or *ovula Nabothi*, which secrete the thick mucus usually plugging up this part of the canal. These are closed follicles, and it is probable that, at certain periods, they burst, discharging their contents, and are succeeded by the development of new follicles.

Surrounding the os uteri there are several tongue-like processes of mucous membrane, the villi of the os uteri. Each contains a vascular loop, and is covered with squamous epithelium.*

The nerves of the uterus are derived from the hypogastric plexus. According to Dr. Beck, the nerves spread out upon the surface of the uterus itself are few in number, and consist of branches which do not unite with each other so as to form a plexus. Dr. Lee describes numerous ganglia connected with these nerves; and his dissections would appear to show that the uterus is much more abundantly supplied with nerves, than is admitted by anatomists generally. We are not, however, prepared to admit that the textures displayed in the elaborate dissections of Dr. Lee, are entirely or even in great part nervous, or that the bodies which he has represented as ganglia, are really of this nature. This anatomist, like

* These villi have lately been carefully described by Dr. Tyler Smith, Med.-Chir. Trans., vol. xxxv.

William Hunter, and Tiedemann, considers, that in the gravid uterus the nerves become much increased in size; an opinion which Dr. Beck has failed to confirm in his very careful and elaborate dissections.*

The *ligaments* of the uterus are described in works on descriptive anatomy. They are the anterior and posterior ligaments, the broad ligaments and the round ligaments. The two first being merely folds of peritoneum, the latter a rounded cord about five inches in length. Mr. Rainey has shown that the round ligament of the uterus contains numerous striped muscular fibres. He describes the round ligament as arising by "thin fasciculi of tendinous fibres; the inner one from the tendon of the internal oblique and transversalis near the symphysis pubis, the middle one from the superior column of the external abdominal ring near to its upper part, and the external fasciculus from the inferior column of the ring just above Gimbernat's ligament."

The fibres pass backwards and outwards, soon become fleshy, unite to form a rounded cord which runs between the layers of peritoneum forming the broad ligament of the uterus, and is inserted into the upper and anterior part of the uterus. The action of these fibres would be to draw the uterus forwards and thus elongate the vagina.†

Vagina, and Accessory Female Organs of Generation.—The vagina consists of an external or fibrous layer, and a muscular coat. It is lined by mucous membrane.

The fibrous tissue of the external coat contains many fibres of the yellow elastic element, and a large network of vessels, with plexuses of veins which form an erectile tissue.

The muscular fibres run partly in a longitudinal direction, and are partly arranged in transverse bundles which encircle the vagina.

The mucous membrane is of a pale reddish colour, thrown into many small, firm, prominent folds, *columnæ rugarum*, separated by fissures. The epithelium of the vagina is very large, and of the scaly variety. These cells are almost always present in the urine of females. The nucleus is usually seen very distinctly, and is of an oval form. They present examples of the largest epithelial cells in the body. Close to the external orifice, the mucous membrane forms a reduplication, termed the hymen, which extends across the posterior part of the opening.

There are two small glands, the *glands of Bartholini*, in the female, which correspond to Cowper's glands in the male. They are small branched glands, the ultimate vesicles of which are lined with tesselated epithelium. They appear to secrete a clear yellowish thick mucus.

The corpora cavernosa of the *clitoris* correspond in structure to those of the penis of the male, but are of very small size. Valentin has described helicine arteries, as in the penis. In the mucous membrane of the external female genital organs, are numerous glands;

* Phil. Trans. 1846, part ii.

† Phil. Trans. 1850, part ii. p. 515.

and in the labia majora are some sebaceous glands, opening into the hair follicles, which are so numerous in this region.

The papillæ in this situation are very numerous and highly developed, and are covered with scaly epithelium. The submucous tissue is abundant, loose, and without fat; it contains many fibres of the yellow element. At the labia majora, the mucous membrane becomes continuous with the external skin, to which it gradually approaches in structure.

Urethra.—The female urethra is much shorter and wider than that of the male. It is about an inch and a half in length, and terminates in the *meatus urinarius*, which opens in the vulva between the nymphæ. This canal may be enormously dilated without danger, and a very large calculus has often been extracted from the female bladder through it. The mucous membrane, especially near the bladder, contains many follicles.

Besides the works already referred to in the Notes, the authors recommend the reader to consult the following: Kölliker's "Manual of Human Histology," translated by Busk and Huxley, Cavendish Society; Dr. Barry's Papers in the Phil. Trans., 1838–40; Dr. Lee's "Memoirs on the Ganglia and Nerves of the Uterus," 1849; Dr. Snow Beck "On the Nerves of the Uterus," Phil. Trans., 1846; Quain and Sharpey's Anatomy.

CHAPTER XXXIX.

PUBERTY.—MENSTRUATION.—MATURATION AND DISCHARGE OF OVA.—FORMATION OF CORPORA LUTEA.—STRUCTURE OF CORPUS LUTEUM.—DISTINCTION OF THE TRUE FROM THE FALSE CORPUS LUTEUM.

The period of puberty commences at different ages, is characterized by different phenomena, and lasts during widely different periods of time, in the two sexes. In the *male*, puberty seldom occurs before the fourteenth or fifteenth years. It is marked by increased development of the genital organs, the formation of spermatozoa, and the occurrence of sexual feelings. Besides these changes, however, there are others scarcely less striking and characteristic, as the growth of hair on the face and pubes, increased development and symmetry of the limbs and general outline of the body, an alteration in the physiognomy, a greater capacity of the respiratory organs, and a striking change in the character of the voice, which becomes of a deep tone, very different from that of boyhood and of the female sex. This alteration of the voice does not take place in eunuchs, who retain throughout life a shrill tone, of higher pitch, approximating more in character to the female voice than to that of the male. Perfectly-formed spermatozoa are not found in the genital organs of the male before the period of puberty. The power of procreation lasts much longer in the male than the female, and often continues up to

the sixtieth or sixty-fifth years; and instances of virility are recorded at the advanced age of one hundred.

In the human *female*, puberty is likewise characterized by the occurrence of certain local changes in the generative organs, and also by changes of a more general character occurring in the body. About this time, which usually occurs between the thirteenth and sixteenth years, but somewhat earlier in hot climates, the organs of generation undergo a considerable increase in size; the breasts enlarge, and an increased deposit of fat takes place over the surface of the body generally. The most important indication, however, of puberty, or aptitude for procreation, in the human female, is the appearance of the *catamenia*. Nevertheless, instances have occurred in which the menstrual secretion was retarded for several years, or even in which it never appeared, although the susceptibility for procreation existed, and impregnation had taken place. Hence, although the presence of the menstrual discharge indicates that the period of puberty has arrived, its absence cannot be looked upon as a proof of the want of procreative power; while in some instances, the catamenia may appear regularly without impregnation ever taking place, in consequence of certain abnormal conditions of the organs of generation. The period of puberty is more affected by the habits of the individual than by temperature, although the latter probably exerts some slight influence. In Africa, menstruation is said to be common as early as the eighth or ninth year; but in colder climates, and in our own country, it seldom occurs before the thirteenth year, and usually not till the fifteenth or sixteenth year. Still cases are on record in which the catamenia appeared in young children in this country; and their appearance was marked by enlargement of the breasts, and other changes indicative of puberty.

In both sexes, the period of puberty is much influenced by the conditions under which the child is placed. Habits of indolence, luxury, and indulgence, tend to the early development of puberty; while, on the contrary, it occurs some years later in those who are inured to active employments, and who are placed under conditions favourable for promoting bodily vigour and mental activity.

The catamenia occur at intervals of a month, and the discharge usually continues from three to six days. It ceases during pregnancy and lactation, and, in most women, does not recur after the forty-fifth to the fiftieth year; but exceptions to these statements are met with from time to time.

At each menstrual period, the mucous membrane of the uterus, and of the generative organs generally, becomes turgid, in consequence of an increased local determination of blood. The mucous surface of the uterus is covered by a sanguineous discharge, which escapes from the turgid vessels.

Of the Menstrual Fluid.—The quantity of the menstrual secretion varies considerably, as also do its characters. In this country, from four to eight ounces are lost at each menstrual period, but sometimes the quantity is much greater. It is of a dark red colour from the numerous blood corpuscles it contains, and is perfectly fluid, as it is

free from fibrine, a character which distinguishes it from ordinary blood. Besides blood-corpuscles, it contains a number of small, pale granular cells, and large corpuscles, containing numerous small oil-globules, the so-called *granular corpuscles*.

Dr. Letheby has published an analysis of menstrual fluid which had accumulated to the extent of forty ounces, in consequence of an imperforate hymen. It was thick and black, and it contained no fibrine. Under the microscope were detected altered blood corpuscles, exudation or granular corpuscles, mucus cells, epithelium, and granules.

Water	857·4
Solid matter	142·6
Fat	5·3
Albumen	69·4
Globuline	49·1
Hæmatin	2·9
Salts	8·0
Extractive matter	6·7

Maturation of Ova, and their Discharge from the Graafian Follicle.—The most important of the phenomena, however, accompanying menstruation, is the maturation and discharge of ova from the ovary. At these periods, a Graafian follicle becomes enlarged, projecting considerably from the surface of the ovary, and distended with fluid. Its wall becomes thin at one point, where it at length gives way, and the contents of the follicle escape into the Fallopian tube. The ovum has but rarely been detected in the Fallopian tube, which is scarcely to be wondered at when we consider its small size, and the very few cases in which we have an opportunity of searching for it with a chance of success. It has, however, been actually seen in one case in the human female examined by Dr. Letheby, and in another by Mr. Hyett. In animals, it may be detected without difficulty, although it is only of late years that the escape of the contents of a Graafian follicle at each menstrual period has been placed beyond a doubt. We owe to Dr. Robert Lee, observations, made so long ago as the year 1831, which establish the fact of the rupture of a follicle, and the escape of its contents, at each recurrence of menstruation. Ova have been detected in the ovaries at a very early age.

Dr. Ritchie states, that, even during childhood, there is a continual rupture of ovisacs and discharge of ova taking place; but it is not until the period of puberty that the number of ovisacs becomes very great, or the ova are perfectly developed and capable of being impregnated. At this time, the stroma of the ovary is seen to be everywhere studded with ovisacs in various stages of development; the largest and most mature occupying the peripheral parts of the organ, while those containing mature ova, which are about to be discharged, form considerable prominences, projecting from the surface of the ovary.*

* Dr. Barry calculates that, in the ovary of the cow, about the period of puberty, there are as many as two hundred millions, corresponding to a cubic inch of the stroma.

The discharge of ova from the ovary in animals, as in the human subject, occurs only at certain definite periods, which vary much in different animals. It is only at these times that the female animal will receive the male, and that the aptitude for conception exists. At such a time the animal is said to be "in heat" or "rut." In the bitch, this period occurs twice in the year, and lasts for about a fortnight each time; in the sheep and in the cow, and in domestic animals generally, it occurs much oftener than in wild animals, and the periods of recurrence are not definite.

If the ovary of an animal be examined at the time of "heat," it will be found turgid with blood, and several Graafian vesicles will be seen projecting from its surface, forming prominences, the most superficial portions of which appear quite thin, and almost ready to rupture and permit the escape of the contents of the follicle. At the same time, a more abundant secretion of mucus takes place from the walls of the vagina and contiguous parts. In a few instances, also, a bloody discharge has been detected in the vagina; but it must be distinctly borne in mind, that this is not a constant phenomenon. It only occurs in small quantity, and it never appears at each successive period of heat, while it is always accompanied with increased sexual desire.

It may be considered as established, that in the human female, at or about the period of menstruation, a discharge of ova takes place; and at these times the ovaries are extremely turgid, and their vascularity is much increased. From very numerous observations, it has been distinctly proved, that conception is more likely to take place a few days after menstruation than at any other period, a fact which has led Naegele to fix the period of delivery at nine months and eight days after the last menstrual discharge; while, in a few instances, the ovum has actually been seen within a very short time after its escape from the Graafian follicle.

From these facts, most physiologists have been led to look upon the menstrual periods in the human female as identical with those of heat or rut in animals; a view which has been especially advocated by Bischoff.

The maturation and escape of ova, then, in all animals, is a periodical phenomenon, and even in the human subject, if not accompanied with, is shortly followed by, increased sexual desire; while, in animals, sexual intercourse takes place at these times alone. The rupture of the follicle is probably due to the increased local determination of blood at these periods, by which the contents of the Graafian follicle are forced towards the surface of the ovary. Besides the escape of a certain quantity of blood into the follicle, an exudation takes place from its lower part, so that the contents of the follicle are gradually forced towards the surface, and at the same time, the structures at this point gradually become thinner, until at last the peritoneal coat, and the thin layer of the stroma, give way, and the contents of the follicle escape through the fissure. The opening soon closes, leaving a small *cicatrix*.

After the ovum has arrived at the most superficial portion of the

follicle in the manner just described, and is about to escape, the fimbriæ of the Fallopian tube grasp the ovary; and the ovum, after it has escaped from the ruptured follicle, ordinarily falls into the funnel-shaped cavity at the base of the fimbriæ, whence it is transmitted into the Fallopian tube, along which it is gradually propelled, chiefly, no doubt, by the vermicular contractions of the walls, but in part, also, by the vibration of the cilia which line its interior, into the uterus. In some distressing cases, happily very rare, the ovum falls into the cavity of the peritoneum, instead of entering the Fallopian tube, and the embryo becomes developed in this situation. These cases usually terminate in death. Sometimes, however, the remains of the fœtus escape by suppuration through the abdominal walls, or into the intestine.

Immediately after the escape of the ovum from the ovary, certain peculiar and characteristic changes ensue in the follicle which contained it, and these are influenced by the occurrence of impregnation. If impregnation has taken place, the lining membrane of the uterus also becomes the seat of peculiar changes, which do not occur under other circumstances. The changes which affect the ovum itself, consequent upon impregnation, will be more conveniently considered when we have referred to the manner in which *corpora lutea* are produced. The mode of formation of the membrana decidua will be alluded to afterwards.

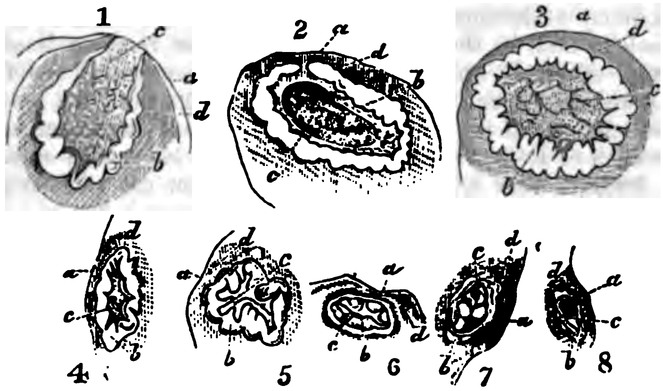
Formation of Corpora Lutea.—If the Graafian follicle of a mammalian animal be examined soon after the escape of the ovum, it is found to be almost completely filled with an exudation, similar to that which, by its gradual increase in quantity, has caused the ovum to be carried to the surface of the follicle. In a short time, the outer portion of the follicle is occupied by a firm yellow substance, which is probably formed from plasma, exuded from its walls. After many careful examinations, Dr. Lee has been led to conclude that this yellow matter is deposited external to both the membranes of the follicle.* Montgomery regards it as situated between the layers, while some authorities look upon the internal surface of the inner membrane as the precise seat of its formation. Dr. Zwicky considers the large cells, of which the yellow matter is composed, as modifications of the small cells of the immature follicles. Their nuclei are large and well defined, and they contain numerous oil-globules in their interior. Although bodies, which are liable to be taken for corpora lutea, are, from time to time, found in the virgin ovary, a fœtus has never been found in the uterus without the formation of an unmistakable corpus luteum. Haller's remark, therefore, "nullus unquam conceptus est absque corpore luteo," although made so many years ago, may still be regarded as strictly true.

At first, this exudation is of a dark brown or brownish-red colour, resembling effused blood; but soon the colour becomes paler, while its consistence is firmer and more dense. At length the follicle is seen to be occupied with a firm mass, which appears to be formed

* Med.-Chir. Trans., vol. xxii.

from a secretion poured out from its walls, which, from its yellow colour in man and many animals, has been called *corpus luteum*.

Fig. 268.



Corpora lutea of the human female at different periods. 1. Eight days after conception. 2. At the end of the second month. 3. At the termination of the fourth month. 4. At the seventh month. 5. Two days after delivery. 6. Twelve weeks after delivery. 7. Corpus luteum of menstruation, or false corpus luteum, four weeks old. 8. Corpus luteum of menstruation thirty days old.
a. Capsule of ovary. *b*. Substance of corpus luteum. *c*. Coagulum occupying cavity in its interior. *d*. Stroma of the ovary.—Altered from figures by Montgomery, Kölliker, and Dalton.

Hence, for every follicle in the ovary from which an ovum is discharged, a corpus luteum will be found. In cases of twins, two corpora lutea are always present; sometimes one in each ovary, sometimes two in one. The characters which the corpus luteum exhibits, and the extent to which the changes giving rise to its formation undergo, will be determined by the circumstance of the ovum being impregnated or not.

Bischoff proved decisively that the ova in mammalia were detached from the ovary at the time of heat, without coition taking place; and that corpora lutea were formed in the ovaries, just as if coition had occurred, and impregnation had taken place.

Raciborski, from numerous experiments upon animals, has shown that whether the rupture of the follicles is or is not accompanied by coitus or by fecundation, the appearance of the lesion which results is, in both cases, absolutely identical.

Nevertheless, the corpus luteum of pregnancy, except in its earliest stages, has been admitted by all observers, to possess characters by which it may be distinguished from the corpus luteum formed in a follicle from which an ovum has been discharged without subsequent impregnation having occurred. Hence, *true* and *false* corpora lutea have been described; the true occurring only when conception has taken place, while the false are met with in the virgin ovary. This distinction must undoubtedly be recognized; but there is every reason to believe that the development of a true corpus luteum takes place in obedience to similar nutritive changes which determine the formation of this body, proceeding to a much greater extent than in the case of the false or virgin corpus luteum in consequence of their

being promoted by the increased determination of nutritive pabulum and the greater vascularity of the ovaries when impregnation has occurred.

In the cow (according to Dr. Dalton), the corpus luteum reaches its maximum of development in about two weeks after the rupture of the vesicle, and in three weeks more all that remains is a small yellowish spot. If, on the other hand, the rupture of the follicle be followed by impregnation, the corpus luteum does not attain its greatest size till about the middle of the seventh month, and at the termination of the eighth month, it is still of large size, and sometimes forms a very remarkable prominence on the surface of the ovary.

The corpus luteum of menstruation is smaller than that following conception; its yellow colour appears very rapidly, and soon fades. In the course of one or two months after their first appearance, they are no longer to be distinguished. Virgin corpora lutea are not vascular, and cannot be injected.

If a section of the corpus luteum be made, a small cavity will be found in the interior, from which several lines appear to radiate towards its external surface. This little cavity gradually contracts, and ultimately disappears. According to Dr. Montgomery, within the first three or four months of pregnancy, the cavity is large enough to contain a grain of wheat, and often much larger. The same observer has always found the cavity absent after the sixth month; usually it seems to disappear between the fourth and fifth months. A few months after delivery, the corpus luteum entirely disappears. Dr. Montgomery never saw one later than the end of the fifth month after delivery.

In a medico-legal point of view, the characters of the corpus luteum are sometimes of great importance, and it will be well to recapitulate the most important. The true corpus luteum of pregnancy possesses very well marked characters, by which it may be distinguished from the false corpus luteum.

Its projection from the surface of the ovary; its large size, often equal to that of a mulberry, and its rounded form; the triangular depression and cicatrix upon its surface; the little cavity in its centre during the earlier period of its formation, or the stellate cicatrix during the latter part of pregnancy; its lobulated or puckered appearance; its firm consistence and yellow colour; its great vascularity, as may be shown by injection, and its persistence for some time after delivery, are all important points in which the *true corpora lutea* contrast remarkably with those which are formed where conception has not taken place. The *false corpora lutea* are small in size, and do not project from the surface of the ovary; they are often angular in form, seldom present any external cicatrix, contain no cavity or stellate marking in the centre; the material of which they are composed is not lobulated, and their consistence is usually very soft; they often resemble coagulated blood; the yellow material exists in the form of a very thin layer, or, as is more commonly the case, not a trace of this substance is present. False corpora lutea

are easily broken down, and often consist either of small cysts, containing serum, or of a simple coagulum.

The following works and monographs may be consulted upon the subjects treated of in Chapter XXXIX: Dr. W. Hunter on the "Gravid Uterus," 1794; Sir Everard Home, in the Phil. Trans., 1817; Dr. R. Lee's article, "Ovary," in the Cyclopædia of Practical Medicine, 1834, and his Lectures on the Theory and Practice of Midwifery, 1844; "An Exposition of the Signs and Symptoms of Pregnancy," etc., by W. Montgomery, M. D., 1856: Dr. Ritchie's Papers in the Medical Gazette, vol. xxxvi.; Bischoff, "Beweis von der Begattung unabhängiger Periodischen Reifung und Loslösung der Eier," Giessen, 1844; Raciborski, "Comptes Rendus," 1843; "De la Puberté et de l'Age critique chez la Femme et de la Ponte Périodique," Paris, 1844; M. Pouchet, "Théorie Positive de l'Ovulation Spontanée, 1847; Müller's Physiology, supplement by Dr. Baly; Dr. Paterson's Papers in the Edin. Med. and Surg. Journal, Nos. 142 and 145; Mr. Roberton's "Essays on Menstruation, and on Practical Midwifery," 1851; Zwicky, "Die Metamorphose des Thrombus," Zurich, 1845; Prize Essay on the "Corpus Luteum of Menstruation and Pregnancy," by John C. Dalton, Jun., M. D., Philadelphia, 1851.

CHAPTER XL.

IMPREGNATION OF THE OVUM.—CHANGES IN THE OVUM IMMEDIATELY SUCCEEDING IMPREGNATION.—ROTATION OF THE YOLK.—CLEAVAGE OF THE YOLK.—KÖLLIKER'S OBSERVATIONS.—FORMATION OF BLASTODERMIC VESICLE, OR GERMINAL MEMBRANE.—FORMATION OF DECIDUA.—STRUCTURE OF THE MEMBRANA DECIDUA.—DECIDUA REFLEXA.

Impregnation of the Ovum.—It is exceedingly difficult to give a satisfactory description of the nature of the phenomena occurring in impregnation. It was recently held, by Mr. Newport and other observers, that the contact of the spermatozoa with the exterior of the ovum was sufficient to impregnate it. It was supposed, that liquefaction of the spermatozoa occurred, and that the solution thus formed permeated the vitelline membrane, and impregnated the ovum. The latest researches, however, of the same indefatigable investigator upon the ovum of amphibia, and upon the mammalian ovum, have demonstrated satisfactorily that the spermatozoa actually penetrate and pass through the yolk membrane, and are thus brought into contact with the yolk in the interior. This view was advocated by Dr. Barry several years ago (in 1843), and its accuracy has since been confirmed by the observations of Newport and Bischoff, and also by Meissner.

What becomes of the spermatozoa when they have reached the interior is unknown. They disappear, and become liquefied; but the precise manner in which this occurs has not been determined, neither is it known if they penetrate far into the substance of the yolk.

Micropyle.—In many ova the vitelline membrane is very firm

and hard; and it may be fairly asked, how can the delicate spermatozoa perforate so tough a structure as the investing membrane of the yolk undoubtedly is in these ova? Much light has very lately been thrown upon this part of the process of impregnation by the researches of our friend, Dr. Ransom, of Nottingham, by those of Professors Müller and Remak upon the impregnation of the ova in fishes, and by the investigations of Leuckart, Leydig, and Meissner, upon the eggs of insects, mollusks, and some of the radiata.

These researches establish the fact of the existence of one or more pores or tubes passing through the coriaceous envelope, and opening upon its interior. Leuckart has shown that these pores are characteristic of all insect ova.*

In July, 1854, Dr. Ransom made some very important observations upon the ova of the stickleback, and demonstrated the existence of a funnel-shaped depression, pierced by a canal, which passes through the chorion in the unimpregnated ovum. This is the *micropyle*, through which the spermatozoa pass to the interior of the ovum. "In the act of impregnation, one or more (as many as four have been seen) spermatozoids pass into the microplye. Actively moving spermatozoids may remain in contact with the chorion for eighteen minutes at least without producing any sensible change in the ovum, provided none of them enter the micropyle; but when one is seen to enter, in about a quarter of a minute a change is observable."†

Dr. Ransom has found the micropyle in all the fresh-water fishes which he could obtain.

The existence of the *micropyle* in the mammalian ovum has not yet been satisfactorily proved. Remak, however, regards certain streaks existing in the zona pellucida as pores or micropyles through which the spermatozoa may pass.

Changes in the Ovum immediately succeeding Impregnation.—The period of time at which the ovum leaves the ovary, and passes into the Fallopian tube, varies considerably in different animals; sometimes it occurs within a few hours after impregnation, while in other instances, days, or even weeks, may elapse between the time of coitus and the escape of the ovum from the Graafian follicle. In the dog, the ovum may sometimes be found in the Fallopian tube within thirty-six hours after coitus, and at others, not until ten or twelve days afterwards. In the roe-deer, four months are said to elapse between the act of impregnation and the escape of the ovum, according to the observations of M. Pockels. About the time that the ovum leaves the ovary, the cells of the membrana granulosa immediately surrounding it undergo a curious change of form, becoming club-shaped; their pointed extremity being attached to the zona pellucida, by which a stellate appearance is produced (fig. 271, B). Each cell contains a nucleus; and the ovum, with these radiating cells, presents a stellate appearance. The cells afterwards become round, and disappear about the time that the ovum reaches the

* Müller's Archiv., 1855.

† Proceedings of the Royal Society, vol. vii. No. 7, Nov. 23d, 1854.

uterus, except in the case of the rabbit, where Bischoff has observed that they are lost as soon as it enters the Fallopian tube.

Soon after the escape of the ovum from the follicle, and in some instances, even before this, the germinal vesicle disappears. According to the observations of some observers, amongst whom may be mentioned Barry and Wagner, the germinal vesicle is the seat of cell-formation.* The nature of the earliest changes, however, are very obscure. Eventually, two cells result, which are destined to undergo subsequent division and subdivision.

As the ovum passes along the Fallopian tube, it increases somewhat in size; the yolk becomes of firmer consistence, and shrinks a little, so as to leave a cavity between it and the zona pellucida, which is occupied with a clear fluid. The original vitelline membrane itself, according to Dr. Barry, disappears by liquefaction. The external investing membrane seems to be derived from the mucous membrane of the Fallopian tube, and it is this which at length becomes developed into the chorion.

Dr. Ransom describes the changes in the yolk immediately resulting from impregnation in the stickleback's egg, as follows: "About fifteen or twenty minutes after impregnation, a remarkable and more vivid contraction begins, causing the yolk to pass through a series of regularly recurring forms. The contraction begins on one side, near the equator, and soon forms a circular constriction, which gives the yolk the figure of a dumb-bell, the longer axis of which is the polar axis of the egg. The constriction travels towards the germinal pole, and next produces a flask-shaped figure: this is at length lost by the constriction passing on, and the round form is regained in about a minute. This wave reappears, and travels forward again, without any distinct period of rest; and I have seen these movements continue for forty-five minutes, though towards the latter part of this period they are less distinct and more limited in extent. The germinal mass itself, during these contractions, which strongly resemble the peristaltic movements of the intestine, undergoes changes in form, and has increased in bulk and distinctness. These movements are unaffected by weak galvanic currents. Cleavage begins in about two hours after impregnation: no embryonic cell was observed before it began, nor in any of the cleavage masses."

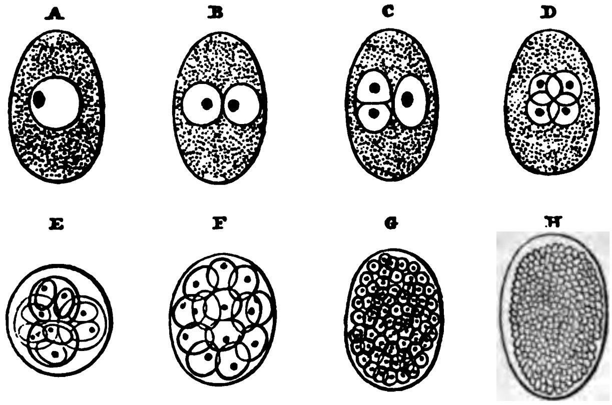
Rotation of the Yolk.—At a very early period after impregnation, Bischoff has observed, in the ovum of the rabbit, guinea-pig, and some other animals, the very interesting phenomenon of the rotation of the yolk. The movements were of a regular rotatory character, and were produced by the active vibration of exceedingly delicate cilia, which had become developed upon the surface of the yolk. This interesting movement may be observed in the ova of frogs and other animals. It can always be seen in those of the common water-snail (*Limnæus stagnalis*), and forms a most interesting object for observation.

Cleavage of the Yolk.—Soon after the ovum has become impregnated, and the germinal vesicle has disappeared, the yolk of the mammalian animal divides into two large cells, and each of these again subdivides into two, so that the yolk mass now consists of four cells, which soon become sixteen in number; these sixteen, thirty-two; and so on, until at last the yolk consists of an aggregation of

* J. Müller has shown that in *Entochoncha mirabilis* (one of the mollusca), the germinal vesicle does not disappear, but forms the origin of the embryonic cell in the centre of the yolk.

In the mammalia, it is the first of these three modes which is followed. The entire yolk divides, its particles collecting themselves round cells resulting from the division of the embryo-cell, until the yolk-membrane appears to be entirely occupied by granular contents; in this stage it is often termed the "mulberry mass."

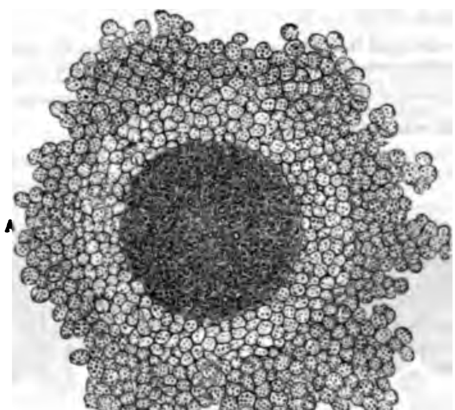
Fig. 270.



Multiplication of cells in the yolk. The first four figures are ova of Ascaris dentata; the remainder, of Cucullanus elegans. After Kölliker.

Formation of Blastodermic Vesicle, or Germinal Membrane.— About the time that the ovum reaches the uterus, the segmentation is complete, and in its general appearance it much resembles the ovarian ovum; but according to Bischoff, upon careful examination, it is found that the apparently granular mass is really aggregated into minute spherical masses, in the centre of each of which is situated a clear vesicle. Soon each of these collections of granules becomes surrounded with an investing membrane, so that cells are

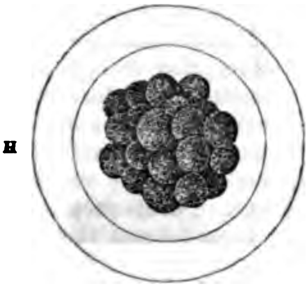
Fig. 271.



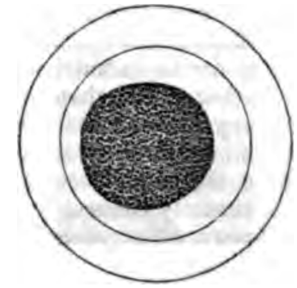
Ovum from the ovary of the Guinea-pig, surrounded by the membrana granulosa, through which the zona pellucida is distinguished.

Fig. 271.

H



An ovum also from the upper part of the uterus, showing the further subdivision of the yolk; but the separate portions are beginning to become incorporated.



I

An ovum from the upper part of the uterus, on the sixth day. The yolk-masses have become incorporated into a single mass, which does not entirely occupy the cavity of the zona pellucida.

All the ova delineated in Fig. 271 have been copied from Bischoff's beautiful Memoir on the Development of the Guinea-pig. Giessen, 1852.

formed, the nuclei of which are represented by the clear central vesicle. The more peripheral cells are first formed, and these from mutual pressure assume a pentagonal or hexagonal form; they become flattened, and united together at their margins, like pavement epithelium. The same process takes place in the interior of the yolk-mass, and as the cells are formed they pass towards the surface, and thus the thickness of the layer first produced becomes increased. A clear fluid only occupies the central part of the yolk. Thus, after the termination of the cleavage process, a membrane composed of cells is formed within the zona pellucida, which Bischoff has termed the "*blastodermic vesicle.*" Soon after the formation of this membrane, but not until it has increased in thickness by the addition of new cells upon its inner surface, formed from the contained yolk-mass, an opaque roundish spot, consisting of cells and nuclei, makes its appearance at one spot. It is in this space, or "*area germinativa,*" that the first traces of the embryo appear; and it is developed upon the surface of the "germinal membrane," or "blastodermic vesicle," being covered only by the zona pellucida. As occurs in the bird's egg, the germinal membrane soon becomes divided into two layers: an *external* or "*serous layer*" or *animal layer*, in which the brain and nervous system and different organs of animal life are developed; and an *internal* "*mucous*" or *vegetative layer*, from which the alimentary canal and organs of vegetative life take their rise.

At the same time that these changes are taking place in the interior, the albuminous layer on the external surface of the ovum coalesces with the zona pellucida, forming a single membrane, from which the chorion is formed, or, as maintained by Dr. Barry, the zona pellucida is first removed, and a completely new investing membrane produced.

Formation of Decidua.—Besides the changes which occur in the ovum immediately after conception, which result in the formation of the embryo, and the development of a new covering termed the *chorion* upon its external surface, alterations of another order are

Professor Goodsir, the greatly increased thickness of the membrane is due. In the mucous membrane of the uterus of the bitch, Dr. Sharpey has described two distinct kinds of glands, one simple and the other compound. The openings of both these forms of glands may be readily seen upon the surface of the mucous membrane; and they soon increase in dimensions, in order to receive the fœtal processes of the chorion, which are covered with epithelium, similar to that lining the follicle. Immediately before the large compound glands open upon the surface, Dr. Sharpy describes their tube as forming a dilatation or cell, into which a fœtal process of the chorion is received. At the bottom of this cell the duct may be seen; and as it passes towards the deep surface, it is observed to form the branched compound gland. At parturition, the vessels of course come away with the decidual membrane, as well as the cells just referred to, but the ducts and branching terminations of the glands remain behind. From this arrangement it follows that, in the bitch, the secretion elaborated from the system of the mother by the agency of these glands is brought into close contact with the vessels of the fœtus, and afterwards absorbed by them.

Fig. 273.

Uterine glands of the bitch. Twelve diameters. 1. Simple glands. 2. Compound glands. After Dr. Sharpey.

In the human decidua, the openings of the glands may be distinctly seen, and their epithelial lining readily traced. The tubes can be followed through the membrane; in fact, from numerous observations, there can be no doubt that, like the decidual membrane in the bitch, the human decidua consists really of the altered mucous membrane of the uterus.

Fig. 274.

B

Thin section of human decidua soon after impregnation had taken place, showing glands divided transversely. Magnified twelve diameters. 1. Tube with epithelial lining. 2. Tube from which the epithelium has escaped. After Dr. Sharpey.

Leydig has seen ciliary motion in the uterine glands of the sow.

Next we have to consider how it is, that the ovum becomes covered with the decidual membrane. Dr. W. Hunter looked upon the decidua as a closed sac, separating the uterine cavity from the openings of the Fallopian tubes. When the ovum descended, he supposed that it pushed the decidua, as it were, before it, and thus became covered in the same manner that the viscera are invested with peritoneum; and hence, Dr. Hunter termed that portion of decidua covering the ovum, *decidua reflexa*, while that lining the uterus was called *decidua vera*. As the ovum increased in size, that part of it towards the Fallopian tube, which of course remained uncovered by the reflexa, at length received a covering, which was termed *decidua serotina*.

Decidua Reflexa.—Since the time of Dr. W. Hunter, much differ-

"On the Structure and Functions of the Membrana Decidua and the Uterine Glands," in Müller's Embryology, translated by Dr. Baley; "De Evolut. Strongyli Auric. et Ascarid. acum. Vivip.," Diss. Inaug. Erlangæ, 1841; Bischoff, "Entwickel. des Hundeeies;" Vogt, "Untersuchungen über die Entwickelung der Geburtshelfer-kröte Solothurn," 1841; Goodsir's "Anatomical and Pathological Observations;" M. Coste, "Comptes Rendus," 1847; Dr. Ransom, "On the Impregnation of the Ovum in the Stickleback," in the Proceedings of the Royal Society, vol. vii. No. 7, 1854; Leuckart, "On the Micropyle and Minute Structure of the Egg-shell in Insects," Müller's Archives, 1855.

CHAPTER XLI.

ON THE DEVELOPMENT OF THE EMBRYO—EARLY CHANGES IN THE BIRD'S OVUM—AREA PELLUCIDA, AREA GERMINATIVA, AREA VASCULOSA—SEROUS AND MUCOUS LAMINÆ—INVESTING MEMBRANE AND MEMBRANA INTERMEDIA OF REICHERT—CHANGES IN THE MAMMALIAN OVUM—PRIMITIVE STREAK—FORMATION OF DORSAL AND VENTRAL LAMINÆ—FORMATION OF THE AMNION—BRANCHIAL FISSURES AND ARCHES—HEART AND LARGE ARTERIES—ALLANTOIS—DEVELOPMENT OF THE HUMAN EMBRYO.

In the last chapter we described the earliest changes resulting from impregnation, and traced them up to the formation of the germinal membrane, and the first appearance of the embryo. We have now to consider the manner in which the development of the embryo takes place, and the mode in which the different organs are evolved. It will be most convenient to describe, as briefly as possible, the earliest changes occurring in the bird's egg, in the first instance, and then to consider the development of the mammalian ovum, and that of the human subject.

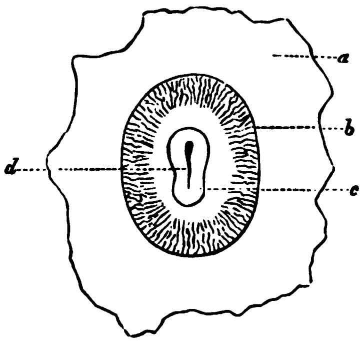
Early Changes in the Bird's Ovum.—In considering the nature of the earliest changes in the egg, resulting from impregnation, but which are dependent for their commencement and continuance upon a temperature varying from 95° to 104° F., we must premise that the yolk of the bird's egg consists of two distinct portions, one which undergoes segmentation, and alone takes part in the formation of the embryo—*the germ-yolk;* the other, and by far the larger portion, does not undergo segmentation, and takes no part in the formation of the germ, but provides the pabulum for its development and nutrition, whence it is termed the *food-yolk.*

Area Pellucida, Area Germinativa, and Area Vasculosa.—A few hours after the egg has been exposed to a hatching heat, it will be found that the *germ* has become less adherent to the vitelline membrane. It has assumed a more membranous appearance; and about the sixth or seventh hour, a clear space may be discerned in its centre. This increases gradually, until it is about a line in diameter. It is called the *area pellucida.* The darker and more granular part, external to the area pellucida, is the *area germinativa,* in which may

area pellucida, which lies in the transverse axis of the egg, appears a line, thicker at one extremity than the other. This is the *first trace* of the embryo, and is called the *primitive streak* or the *nota primitiva.*

About the third day of incubation, on each side of the primitive streak, appear two ridges or crests, which are termed *laminæ dorsales*. These gradually arch over, and at length inclose the brain and cord. The chorda dorsalis occupies a position underneath the spinal cord, and appears as a thin gelatinous thread, which corresponds to the axis of the bodies of the vertebræ, which latter, however, are not formed from the chorda dorsalis, but are developed from a double row of four-sided white spots, or *vertebral plates*, arranged symmetrically on each side of the central chorda dorsalis. Passing downwards from the dorsal laminæ, on each side are the *ventral laminæ*, which tend to inclose a space below the chorda dorsalis, like that inclosed by the *dorsal laminæ* above it. The former contains the large vessel of the trunk (fig. 277); the latter the central organs of the nervous system. In this way are produced the *hæmal arch* and the *neural arch* of the vertebræ.

Fig. 275.



Portion of germinal membrane about the sixteenth hour of incubation. *a.* Germinal membrane. *b.* Area vasculosa. *c.* Area pellucida. *d.* Nota primitiva or embryo.

Soon the embryo, and that portion of the germinal membrane immediately connected with it, become somewhat raised; the embryo itself taking the form of a boat with its concave surface downwards. This is the first appearance of a visceral cavity, bounded by the ventral laminæ, in which the ribs and the transverse processes of the vertebræ are formed.

That part of the most superficial layer of the germinal membrane, or *serous lamina*, immediately surrounding the embryo, forms a prominent fold which soon rises above the surface. According to Reichert, however, the fold is *formed* from the most superficial layer of the *membrana intermedia*, and is only covered by the investing membrane. Each fold approaches that on the opposite side, until, by their approximation and communication, a shut sac is formed, into which fluid is poured. In this fluid, the embryo floats. Its open ventral surface gradually becomes closed, until at last it is connected with the yolk only by means of a very narrow pedicle or cord (*umbilical cord*), which consists of a narrow tube passing from the intestine to the yolk, with certain vascular trunks, through which the nutritive matter absorbed by the vessels ramifying upon the surface of the yolk is carried to the embryo. Of this attenuated cord con-

necting the embryo with the yolk sac or *umbilical vesicle* we shall speak at some length hereafter. Thus is formed the amnion, to which we shall have to allude more particularly in Chapter XLIII.

Such are some of the most important changes occurring during the earliest period of incubation in the chick. We shall now consider the nature of those which take place in the mammalian ovum.

Changes in the Mammalian Ovum.

The essential changes which manifest themselves in the early period of the development of the mammalian embryo are very similar to those which we have briefly described as occurring in the bird's egg; but in consequence of the small amount of yolk in the former compared with the latter, and therefore the greater dependence of the embryo for its nutrition upon external sources, certain differences are observed in the development of the mammalian ovum.

It has been already stated (p. 857) that by the time the mammalian ovum has reached the uterus, the process of segmentation is complete. It is also paler and more transparent. The germinal vesicle had disappeared previous to segmentation; but whether its contents become mixed up with the substance of the yolk, or new cell-formations primarily result from it, has not yet been conclusively determined.

By the aggregation of cells upon the surface of the yolk, a sort of membrane, composed of pentagonal cells with nuclei is formed within the *zona pellucida*, or yolk-membrane. This is called the *blastodermic* vesicle, and in its mode of formation nearly corresponds to the germinal membrane of the bird's egg.

The *chorion*, or outermost membrane investing the ovum, is formed by the gradual coalescence of the zona pellucida, and the layer of albuminous material with which it is covered. The chorion is at first smooth, but villi are subsequently developed all over its surface. Beneath the chorion is the blastodermic vesicle, which gradually increases in thickness by the growth of new cells upon its internal surface.

In consequence of the great difficulty experienced in procuring human ova at a very early period in a perfectly normal state, and in sufficient number, physiologists have been compelled to make direct observations upon the lower animals, and to assume that a series of changes precisely similar takes place in the human ovum, an inference which has been of late years fully justified by direct observation. In discussing this part of our subject, we shall, therefore, infer that the early embryonic changes occur in a similar order, and are of the same essential character in all mammalia, except, of course, with reference to the precise period at which they take place, which necessarily differs in various animals, according to the duration of pregnancy. For much that we know of the development of the mammalian ovum, we are indebted to the beautiful researches of Bischoff upon the ova of the dog, rabbit, guinea-pig, and deer.

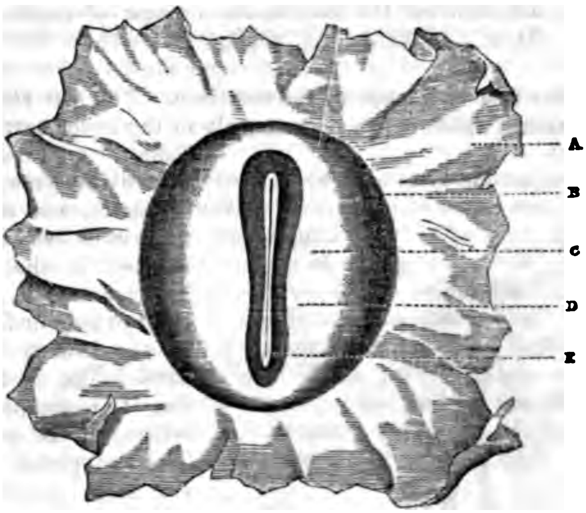
Primitive Streak.—At a period varying from the twelfth to the

sixteenth day, the dog's ovum assumes a more oval form. It is about three lines in length, and about a line and a half in its short diameter. Its external surface is as yet perfectly smooth, for none of the tufts or villosities of the chorion are developed. The central clear space (area pellucida or germinativa) is seen to be surrounded by a darker circle, which eventually becomes the *vascular area.*

In the centre of the clear space a line is soon observed. This is the first trace of the embryo, *the primitive streak,* which appears in the form of a straight white line, or very shallow groove. It lies across the short axis of the ovum, and therefore occupies a position precisely similar to the embryo chick.

The primitive streak is formed in the serous or animal layer of the germinal membrane, beneath the *investing membrane* of Reichert. Bischoff has shown, that in the mammalian ovum the germinal membrane becomes divided into two laminæ, as in the chick.

Fig. 276.



Portion of the germinal membrane of the bitch's ovum, showing the area pellucida and first traces of the embryo, after Bischoff. A. Germinal membrane. B. Area vasculosa. C. Area pellucida. D. Laminæ dorsales. E. Primitive trace. Magnified ten diameters

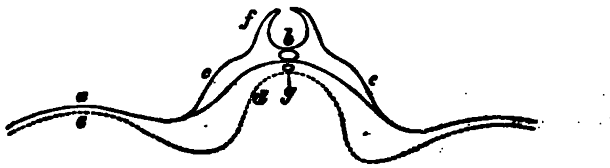
The external lamina is the serous or animal layer, and the internal one is the mucous or vegetative layer. The middle layer, or *membrana intermedia,* described by Reichert, has already been alluded to in page 864, but, according to Bischoff, is not to be detected in the mammalian ovum.

Formation of Dorsal and Ventral Laminæ.—In a short time the cephalic extremity becomes enlarged, and the entire embryo of a guitar-shape in its general outline. As soon as the primitive groove is formed, two oval folds are seen to rise up on each side of it from the serous laminæ (D, fig. 276). These are the *laminæ dorsales,* which gradually approximate; and the groove between them becomes

converted into a canal which contains the central organs of the nervous system.

Reichert supposes that the laminæ dorsales actually take part in the formation of the central parts of the nervous system; but Bischoff considers that they represent the dorsal portion of the embryo, and that the nervous system is developed from their lower and inner part only. About this time a few small square-shaped plates make their appearance in the central portion of each dorsal lamina. These

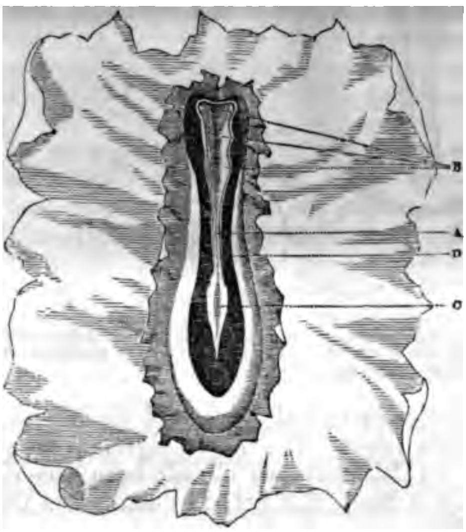
Fig. 277.



Plan showing the mode of development of the dorsal and ventral laminæ. *a.* Serous or animal layer; *e.* Mucous or vegetative layer; *b.* Chorda dorsalis; *c.* Ventral laminæ, arching downwards to inclose the intestines, the rudiment of which is shown at *d*; *f.* Dorsal laminæ arching over to convert the groove into a canal for the spinal cord; *g.* aorta.

plates are the first rudiments of the vertebræ. The soft *chorda dorsalis*, a structure which exists permanently in the lower cartilaginous fishes, appears subsequently between the rows of plates, but this is by no means so distinctly marked in the mammalian ovum as it is in the embryo frog or fish, while in the lowest cartilaginous fishes, as the myxine, the lamprey, and others, it is persistent. The two plates of opposite sides gradually approximate, and ultimately coalesce, including between them a portion of the chorda dorsalis, a temporary structure, which disappears entirely with-without being transformed into any more permanent texture.

Fig. 278.



Germinal membrane with rudiments of embryo of the dog. After Bischoff. A. Primitive groove, not closed. B. The three dilatations corresponding to the three vesicles of the cerebrum. C. Space at lower part of groove or *sinus rhomboidalis*. The streak at the bottom of the groove is the chorda dorsalis.

The *laminæ viscerales*, or *ventral laminæ*, are also developed in the serous layer, and continuous with the laminæ dorsales. They project downwards, and ultimately inclose the anterior portion of the embryo.

In the anterior dilated extremity of the embryo are developed three vesicles, from which the different parts of the brain are ultimately evolved.

Formation of the Amnion.—The upper layer of the serous lamina becomes raised in the form of a convex ridge, which extends entirely round the circumference of the embryo. This ridge, consisting, of course, of two layers of serous lamina, rises up gradually, and the two portions from opposite sides approximate above the dorsal surface of the embryo. The parts of the fold corresponding to the anterior and posterior extremities of the embryo grow faster than other portions, and soon two considerable reduplications are formed. These are called the *cephalic* and *caudal involucra.* The embryo is gradually inclosed by these two layers, which meet over its dorsal surface, and at last coalesce. Thus is formed the *amnion;* and the interval between the inner layer and the embryo is the *amniotic cavity*, which contains a fluid, the *liquor amnii.* The two layers, after some time, become united into one, except at the points where they are separated by the allantois and umbilical vesicle, forming the single amniotic membrane, which lies within the chorion. The outer layer, however, is separated from the inner surface of the chorion by a quantity of viscid albuminous matter, which is subsequently absorbed.

The mode of formation of the amnion in mammalian ova is, therefore, precisely similar to that of the chick, according to Von Baer. Reichert, however, considers that it is formed in a somewhat different manner to that above described.*

Fig. 279.

Fig. 280.

Plans showing manner of formation of amnion, allantois, and umbilical vesicle. *a.* Chorion with villi, most abundant in that part beneath which the allantois is seen, in figure 280; this portion ultimately becomes the placenta. *b.* Space between the two layers of the amnion. *c.* Amniotic cavity. *d.* Situation of intestine, showing its connection with the umbilical vesicle. *e.* Umbilical vesicle. *f.* Situation of heart and vessels. *g.* Allantois.

In mammalia, the formation of the amnion occurs at a very early period, usually within twenty-four hours after the first appearance of the primitive trace.

About the twentieth day the ovum is about ten, and the embryo

* Muller's Physiology, translated by Dr. Baly, p. 1552.

is between three and four lines in lengt
are beginning to make their appearance,
selves round the ovum. That portion, ho
beneath the embryo is the last part of
appear, while the two ends of the ovum
uncovered with villi.

By this time, with the exception of
laminæ dorsales have coalesced, and th
creased in number. The position of th
mined, and the anterior surface of the bo
in by the convergence of the *ventral la*
under part of the dorsal laminæ. At le
appears entirely pinched off as it were,
the yolk-sac or umbilical vesicle by a na
omphalo-enteric duct.

Branchial Fissures and Arches.—At
fissures and three visceral arches may b
The term *branchial* arch is a bad or
that, at a certain perio
the higher vertebrata,
only structures repres
of fishes are branches
scending aorta. In fi
manent, and are surm
They are five in num
there are six, but *one* i
the amphibia a similar
the branchiæ waste aw
its adult form. Usua
arches remain in repti
and man, only one is

Fig. 281.

Visceral or branchial arches of an embryo dog, after Bischoff. *a.* brain; *b.* eyes; *c, d.* right and left auricles; *e, f.* right and left ventricles; *g.* aorta dividing into aortic arches. 1, 2, 3, 4, corresponding visceral or branchial arches.

Heart and large Ar
the heart and large ve
appears first in the
tube, which is a littl
comes completely ben
ment of the heart m
from the beginning of
It appears between the mucous and se
sac, terminating in two or three branch
At this early period even rhythmical m
the fluid in its interior is at this time
vascular trunk immediately after its ori
into four vascular arches, which unite ag
vessel, as it passes down close to the sp
off transverse branches; some of which
tericæ, lying upon the duct of the sam
yolk-membrane, upon the surface of
These vessels absorb the nutrient consti
them to the system of the fœtus. Wi

they form a network over the umbilical vesicle. Their arrangement will be more fully described in Chapter XLIII., on the development of the membranes of the fœtus.

Allantois.—The allantois is first observed as a little solid eminence composed of cells upon the anterior surface of the caudal extremity of the embryo (figs. 279, 280, *g*). A cavity is soon formed, which is continuous at one period with the lower part of the intestine.

The allantois grows very rapidly, and in ruminants soon surrounds the entire fœtus, its outer surface being in close contact with the chorion; but in rodent animals, and in man, its chief office is probably that of conducting the vessels of the fœtus to the chorion.

Development of the Human Embryo.

It was formerly supposed that man, in his development, passed through various successive stages, each of which was said to have its permanent representative among the lower animals; but a doctrine so obviously untrue has long since ceased to have any supporters. Von Baer showed the fallacy of such a statement; but at the same time proved that up to a certain period of development, the changes occurring in the human embryo were precisely similar to those which take place in the development of all other vertebrate animals; that, for instance, up to a certain period of its existence, we should be unable to distinguish the embryo of man, or one of the higher vertebrata, from that of a reptile or a fish. All seem to be developed upon one general plan. The organs are evolved in the same order, and the organic functions in the manner of their performance are precisely analogous. After this point has been reached, however, the distinctive characters are well marked, and then it is very easy to say whether the embryo is to assume permanently the condition of a fish, reptile, bird, or mammal.

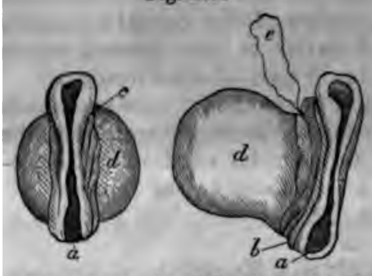
One of the youngest human ova which has been examined, is described by Mr. Wharton Jones, and was aborted in the third or fourth week after impregnation, It was about the size of a pea, and was probably detached at a somewhat earlier period. Villi were seen on one side only of the chorion. At one end of the ovum, lying in the midst of a gelatinous material, was the germinal vesicle, but the embryo was not yet visible upon it.

Dr. Allen Thomson has examined two human ova at a somewhat later period. One was a quarter of an inch, and the other half an inch, in diameter. The embryo was about one line in length (fig. 282). It lay nearly flat upon the yolk-sac, no constriction being as yet formed. The dorsal laminæ were distinct, and had not yet united together. There was neither allantois nor amnion. This ovum was examined about fifteen days after conception.

MM. Pockels and Coste have had an opportunity of examining an ovum about this period, in which the umbilical vesicle and allantois were seen very distinctly. The embryo lay in the amniotic fluid; but the allantois had not yet become connected with the inner sur-

face of the chorion. In another embry
Thomson, about five or six weeks after c
attach
existe
was n
forme
eighth
heart
looped
aspect
was s
yolk-s
anus
umbili
narro
branc
Wagn
ova a
embry

Fig. 282.



A human ovum described and figured by Dr. Allen Thomson, about fifteen days after conception, magnified ten diameters. *a.* The open vertebral canal, bounded by the laminæ dorsales. *b.* Folds of the intestinal groove. *c.* Position of the heart. *d.* Yolk-sac. *e.* A piece of membrane perhaps connected with the formation of the chorion.

server was two and a half lines in le
seen closely applied to it. There were
sures and arches. The age of this emb
rable certainty to be about twenty-five d

Several human ova have been subject
different observers, between three and fo
considered to be in a normal state, an
rence of any morbid change. At this ti
lines in length, and the embryo not more
by an amnion which adheres to it pret
already covered with small villi. Betwe
is a considerable quantity of a viscid
embryo is curved. The anterior cerebr
and immediately behind them are the v
mina. The positions of the ophthalmi
indicated. Three or four visceral arches
fissures between them. The heart is no
jects from the anterior surface of the
anterior and posterior extremities exist i
appendages. The abdomen is complet
reflected over the anterior and posteri
to form the cephalic and caudal involuc

The heart is large, and consists of a
Behind the heart is seen the liver, be
intestine, attached by its mesentery.
large as the embryo, and it is connected
pedicle, the *ductus omphalo-entericus.*
lying between the chorion and amnion
with the vessels which accompany it,
the umbilical cord, enveloped by the am
a tube inclosing these structures.

Fig. 283.

Human fœtus between the twenty-fifth and twenty-eighth days, to show the relative position of the several organs. *a.* Chorion with tufts developed over the greater part of its surface. *b.* Amnion; between the situation of the two *b*'s the amnion forms a sheath which invests the structures which compose the umbilical cord. *c.* Position of Allantois with the vessels upon it which ramify in that part of the chorion where the placenta is developed. *d.* Umbilical vesicle with its narrow pedicle and trunks of omphalo-mesenteric vessels spread out upon its surface. *e.* The point at which it opens into the intestine. *f.* Corpora Wolffiana. *g.* Liver. *h.* Heart. *i.* Rudiments of anterior; and *k* rudimentary posterior extremities. *l.* Branchial fissures and visceral arches. *m.* Cavities of nose and mouth not yet separated. *n.* Rudimentary eye. *o.* Rudiments of ear. After Coste.

consists merely of the appropriation of new material by structures already formed. The further development of the different textures gradually takes place, and the various organs assume their permanent character, until, about the seventh month, the fœtus has attained a length of sixteen inches or more, and, under favourable circumstances, its life may be preserved if it be born at this early period. The testicles descend about the eighth month.

By the end of the ninth month the fœtus has attained the length of eighteen or twenty inches. The head is covered with hair, and the skin becomes invested with a soft pultaceous substance, the *vernix caseosa*, which consists of cells of epidermis, with a considerable quantity of oily material. The *membrana pupillaris* is absorbed. During the latter months of pregnancy, the child lies in utero, with its head downwards, the position in which birth takes place.

The student is referred, for further information upon the subjects treated of in the present chapter, to the works enumerated at the end of Chapter XL., and to the following: Reichert's Observations on the Development of the Chick, in Müller's Physiology, translated by Dr. Baly; Bischoff's Monographs on the Development of the Dog and Guinea-pig; De Graaf, Opera Omnia; Von Baer's Entwickelungs-geschichte; Dr. Thomson, in the Edinburgh Med. and Surg. Journal, No. 140; Wagner, Icones Physiol.; Article "Ovum," in the Cyclopædia of Anatomy and Physiology, by Dr. Allen Thomson.

CHAPTER XLII.

ON THE DEVELOPMENT OF THE DIFFERENT ORGANS.—DEVELOPMENT OF THE SPINAL COLUMN.—OF THE FACE AND VISCERAL ARCHES.—DEVELOPMENT OF THE NERVOUS SYSTEM.—OF ORGANS OF VISION AND HEARING.—DEVELOPMENT OF THE HEART AND AORTIC ARCHES.—OF THE ANTERIOR VENOUS TRUNKS.—OF THE LUNGS.—OF THE THYROID.—DEVELOPMENT OF THE ALIMENTARY CANAL.—OF THE LIVER AND PANCREAS.—OF THE SPLEEN.—DEVELOPMENT OF THE WOLFFIAN BODIES AND KIDNEYS.—OF THE SUPRARENAL CAPSULES.—OF THE ORGANS OF GENERATION.

In the present chapter we have to consider the mode of development of the most important organs of the body; but we do not propose to enter further into the process of development of the separate tissues, as this part of the subject has been already treated of in the preceding chapters upon the anatomy of the different organs.

Development of the Spinal Column.—In man and the higher vertebrata, the spinal column is composed of a number of distinct and separate segments, which are connected together by the intervention of a fibrous material. This gives to the whole column a considerable amount of mobility. In the lower fishes, however, no such division exists; and in the place of numerous vertebræ we have a continuous mass of a soft consistence running through the whole

length of the animal, and known as the *Chorda Dorsalis.* The material of which this is composed is the simplest form of cartilage, consisting entirely of a number of large cells, without the interposition of any matrix or intercellular material between them. In the embryonic condition of all vertebrate animals, we meet with a chorda dorsalis entirely composed of cells, and possessing similar characters to the permanent chorda dorsalis of the cartilaginous fishes. It is seen as a faint streak at the bottom of the primitive groove. Above it, the central organs of the nervous system are formed; and immediately beneath it, is the great artery of the body, with the viscera. At the anterior and posterior extremities of the embryo, the chorda dorsalis tapers to a point. In its earliest condition, it is composed of a perfectly clear gelatinous material, in the anterior extremity of which cells soon make their appearance, and increase in number until the whole becomes cellular. It is surrounded by a delicately fibrous sheath; external to which the blastema, which gives rise to the development of ossifying cartilage, is deposited. In this situation, after a time, cartilaginous rings make their appearance, and merge by insensible gradations into the fibrous sheath. The fibrous structure gradually disappears, and in its place cartilage is formed, while at the same time the substance of the chorda is removed, to give place to the developing cartilage. The cells of the cord, however, are not *transformed* into cartilage cells. Eventually only a portion of the cellular substance remains between the bodies of the vertebræ. At a much later period, cartilaginous arches are formed in the inner part of the dorsal laminæ, which become converted into the *vertebral arches.* The outer portion of the laminæ dorsales becomes converted into muscular tissues and integuments.

The *cranium* is originally formed from an extension forwards of the chorda dorsalis, and its development occurs at a much earlier period than the bones of the face. In the lamprey and the sturgeon, the connection between the chorda and the cerebral cartilage is permanent. In mammalia, those portions analogous to the bodies of vertebræ appear in the basis cranii; and prolonged from these, above, are portions corresponding to the *neural arch* of the *typical vertebra;* and below, parts belonging to the *hæmal arch.*

The body of the *epencephalic* or *occipital vertebra* is represented by a distinct point of ossification, for the basilar process of the occipital bone; its *neural arch* by the expanded portion of the bone itself; its *hæmal arch* by the *scapulæ, bones of arm, forearm,* and *hand,* and the *coracoid processes of the scapula* (*coracoid bones* of oviparous vertebrata).

The body of the *mesencephalic* or *parietal vertebra* is seen in the *basi-sphenoid,* or body of the sphenoid bone; its *neural arch* is formed by the *mastoid portions* of the *temporal bones, the great wings* of the *sphenoid* and the *parietal bones;* its *hæmal arch* by the *styloid process* of the *temporal,* and by the *body* and *greater* and *lesser cornua* of the *hyoid bones.*

The *prosencephalic* or *frontal vertebra* has its body represented by the anterior or *spheno-orbital portion* of the *sphenoid;* its *neural*

arch by the *external angular processes* of the *frontal*, the *small wings* of the *sphenoid*, and the *frontal bone;* its *hæmal arch* by the *tympanic portion* of the *temporal bone*, and by the *articular and dental portion* of the *inferior maxilla*.

The body of the *rhinencephalic* or *nasal vertebra* is represented by the *vomer;* its *neural arch* by the *ossa plana* of the *ethmoid*, and by the *nasal bones;* its *hæmal arch*, by the *palatine*, *pterygoid*, and *malar bones*, by the *squamous* and *zygomatic* portions of the *temporal bones*, and by the *superior maxillary* and *intermaxillary bones*.

In thus briefly describing the manner in which the cranial vertebræ are constructed, we feel great regret that our limited space will not permit us to enter more at length into the beautiful and well-known discoveries of Professor Owen in this department. We cannot too strongly recommend the reader to consult upon this important subject, Professor Owen's "Archetype Skeleton," and his "Homologies of the Vertebrate Skeleton."

Development of the Face and Visceral Arches.—The visceral cavity in the upper part of the embryo, at a very early stage of development, is bounded above by the cerebral capsule; and below, and at the sides, by the anterior visceral arch. Reichert has shown that this arch becomes bent upon itself, and from it are formed above the angle, the *superior*, and below the angle the *inferior*, *maxillary* apparatus.

The *superior maxilla* grows upwards, and unites with a prominence which is seen in the centre of the forehead, the *frontal process* of Von Baer—a space being left between the two superior maxillæ, which becomes the *nasal cavity*. Beneath this, the two bones are connected together by the partition which forms the palate, and which does not appear for some time.

In animals, besides the maxillary bones, there are a pair of narrow bones between them, extending from the interval between the lower portion of the nasal, and the ascending process of the superior maxilla. These are the *intermaxillary bones*, which exist in the human fœtus in a rudimentary condition. They appear to be formed partly from the nasal process of the forehead, and partly from a portion of blastema which is detached from the lower jaw, to which Reichert gives the name of *intermaxillary rudiment*. In man this bone is not developed; but in fishes and amphibia it contains teeth. The intermaxillary bones differ, therefore, in their origin, from the maxillæ, and are probably developed from centres independently of the latter. In the monstrosity familiar to us as *hare-lip*, the superior maxillæ and palate bones of opposite sides do not meet, while the intermaxillary bones are united in the centre, and form a prominent tongue of bone, on either side of which is a deep fissure between the *intermaxillary* and corresponding *maxillary bones* of each side—thus is produced the deformity of *double hare-lip*. The cleft of the palate in these cases usually remains open, and in this way the malformation is increased. The fissure of the *lip* seems to arise from the alteration of the deeper parts; for as such a fissure exists at no

period of embryonic life in the soft parts, it cannot, like the bony fissure above described, be dependent upon an arrest of development.

The *first visceral arch* gives rise to the *superior maxillary apparatus*, consisting of the *intermaxillary bones*, the *vomer*, the *maxillary* and *palate bones*, and the *pterygoid plates* of the sphenoid, the *lower jaw*, and the *malleus* and *incus*.

The *second visceral arch* gives origin to the *hyoid bone*, the *styloid process*, and its ligaments, and the *stapes* of the ear. In animals a great part of this hyoid apparatus becomes ossified.

From the *third visceral arch* arise the *posterior cornu* and *body* of the *hyoid bone*.

In the embryo of mammalian animals, the fourth arch is very indistinct.

Development of the Nervous System.—Reichert has shown that, in their earliest condition, the central organs of the nervous system are composed of two laminæ united in the middle line, so as to form a central groove. This groove soon becomes converted into a canal, except in the position corresponding to the medulla oblongata. In front of this, certain vesicles appear, from which the several parts of the brain are subsequently developed.

These vesicles have been named *Prosencephalon*, *Deutencephalon*, *Mesencephalon*, and *Epencephalon*, by Professor Owen. Of these vesicles, the latter, which corresponds to the cerebellum, is at this early period, the largest of the four. The *mesencephalon*, or vesicle of the corpora quadrigemina, corresponds to the large optic lobes in fishes, reptiles, and birds, which in these classes are only two in number (corpora *bigemina*), and in the adult human brain is represented by the small corpora *quadrigemina* (anteriorly *nates*, posteriorly *testes*). In front of this vesicle is a small one, which is formed before any of the others, and for some time is the most anterior of all. This is the vesicle of the *third ventricle*, and contains the *optic thalami*. These points are all well seen in the fish's brain.

The *prosencephalon*, from which the *cerebral vesicles* are formed, lies in front of this, and at first is extremely small; it bears a proportion to the rest of the encephalon not greater than that which the small, unimportant cerebral lobes of the adult fish bear to its entire cerebrum. The prosencephalon soon, however, increases in size, and becomes much larger than all the others.

Our friend, Professor Retzius, has shown that the three lobes of the hemispheres of the human brain are developed at different periods; the anterior being formed during the second and third months, the middle lobes between the end of the third and beginning of the fifth month, and lastly, the posterior lobes are produced. The cerebellum was seen by Von Baer, in the chick, during the fourth day of incubation. It is formed by the meeting of the laminæ of the spinal cord anteriorly to the fourth ventricle; a short canal is, however, left, which passes towards the corpora quadrigemina or optic lobes, the future *iter a tertio ad quartum ventriculum*.

Bischoff has demonstrated that, at a very early period, nervous matter is formed along the inner surface of the lips of the primitive

groove. These two masses of nervous matter gradually approximate, and thus a tube is produced, the walls consisting of nervous matter—while the central cavity, after contracting, becomes the canal of the spinal cord. The upper portion forms the thin dilatations before described; while at the opposite end is seen a lancet-shaped depression, the future cauda equina, or *sinus rhomboidalis* in birds.

Development of the Organs of Vision and Hearing.—According to Mr. Gray, the eye of the chick is first seen about the thirty-third hour of incubation, in the form of a protrusion from the anterior vesicle, which corresponds to the cerebral lobes, and may be called the *optic vesicle.* This view agrees with that of Baer; but it does not accord with the observations of Wagner or Huschke. The latter observer states that the eye is developed from a protrusion of the vesicle of the third ventricle—from the *deutencephalic enlargement.* The retina is a vesicular body which communicates with the cavity of the brain through the hollow, tubular optic nerve. These points may be observed in the chick during the second day of incubation. Bischoff and Mr. Gray have been unable to confirm the statements of Huschke, with reference to the doubling-in of the retina to form two layers. The latter observes that the fibrous lamina and Jacob's membrane are not developed until after the cellular layer of the retina is formed.*

About the third day of incubation a fissure, which commences at the border of the lens, is seen in the eye of the chick, which Huschke regards as the consequence of inversion of the retina. In fishes, the cleft running from the centre, towards the anterior border of the retina, exists throughout life. In the turtle there is a fissure in the nerve but not in the retina.

Jacob's membrane is not developed before the thirteenth or fourteenth day of incubation. Mr. Gray describes it as forming at this period an exceedingly fine pale granular stratum upon the choroidal surface of the retina.

The circle of the *iris* is seen in the anterior part of the choroid at a very early period; but the pupil is occupied by a highly vascular membrane, the *membrana pupillaris.* This is not attached to the margin of the iris, but to its anterior surface, from which it derives its vessels; and it is probable that it is reflected over the whole anterior surface of the iris, and possibly lines the anterior chamber of the eye. From the margin of the iris, there extends backwards another vascular membrane, the *membrana capsulo-pupillaris,* which is united to the border of the capsule of the lens. This membrane forms a closed sac, the anterior part of which is united to the membrana pupillaris; while the posterior portion lines the anterior concave surface of the vitreous body. This is supplied with vessels by the capsular branch of the arteria centralis retinæ; and at the margin of the iris, the vessels of the membrana pupillaris, and those of the membrana capsulo-pupillaris, communicate with those of the iris.

* Phil. Trans., 1850.

The *eyelids* are first developed in the form of a ring, which extends over the surface of the eye; and afterwards the two portions which are to be developed into the lids become adherent to each other. They separate again, either before birth, as in the human subject—or after birth, as in the carnivora and some other classes.

Organ of Hearing.—The ear appears, at a very early period, upon the vesicular protrusion which ultimately becomes the auditory nerve. It communicates with the cavity of the fourth ventricle, and is situated above the second branchial cleft. The first rudiments of the auditory vesicle were seen by Mr. Gray about the fiftieth hour of incubation in the chick. Throughout the life of the cyclostomous fishes, the ear retains the condition which it presents at an early period of development in the mammalia. Valentin describes the labyrinth as appearing in the form of a separate body of a somewhat elongated form. The inner extremity forms a turn and at this point a second vesicle makes its appearance, which becomes the *cochlea*.

The semicircular canals are developed by a contraction and folding-in of the walls of the vestibule. From Mr. Gray's careful observations, it appears that the labyrinth, about the twelfth or thirteenth day of development in the chick, has an appearance closely resembling the retina at the same time—a point of great interest. Huschke has shown that the Eustachian tube, the cavity of the tympanum, and the external meatus, are the remains of the first branchial cleft, which eventually becomes divided by the membrana tympani.

The *ossicles* of the ear are formed as follows: The *malleus* and *incus*, according to Reichert, are produced from the first visceral arch, which also gives origin to the superior and inferior maxillæ. The *stapes* appears to be produced from the second visceral arch, which also gives rise to the hyoid bone and its suspensory apparatus. The ossification of these little ossicles commences in the fourth month of intra-uterine life.

The development of the mouth and nose have already been alluded to at page 877.

Development of the Heart and Aortic Arches.—The development of the heart is best studied in the chick. It appears towards the end of the second day of incubation, as a small hollow tube between the mucous and serous laminæ of the germinal membrane. About the thirty-sixth hour it has become a simple tube, much curved and twisted upon itself. Posteriorly, it terminates in two or three large venous trunks, which are insensibly lost on the germinal membrane; and anteriorly, it divides into two branches, which unite beneath the vertebral column to form the aorta. The trunk of the vessel again divides into two branches, which are lost on the vascular area. Early on the third day, the heart consists of three cavities—the *sinus venosus*, the *ventricle*, and the *bulbus aortæ*; the first soon becomes divided into the two auricles, and by the fourth day the ventricle assumes its usual form, and the formation of the septum, which divides its cavity into two portions, commences.

About the beginning of the third day, the aortic bulb divides into

four pair of vascular arches. On the fourth day, the first pair disappears and is at length obliterated, and the second pair becomes smaller; but now is formed a fifth pair, which becomes larger on the fifth day, while the second entirely disappears; so that there are at this time only three pairs, and these of nearly equal size.

About the sixth day, a considerable alteration takes place in the circulation. By this time, the allantois forms a vesicle of considerable size, upon the surface of which numerous vessels are spread out. These are derived from two branches resulting from the division of the aorta after it has given off the mesenteric artery. The allantois rapidly increases in size; and as the albumen diminishes in quantity it becomes applied to the membrane of the egg-shell. Through the latter, and through the pores of the shell itself, the air passes to aërate the blood circulating in the vessels of the allantois, which may therefore be looked upon as the great respiratory surface of the chick previous to the formation of lungs.

About the sixth or seventh day, the heart acquires its characteristic form; its cavities have approximated more closely, and become conjoined; the division between the auricles and ventricles can be seen distinctly. The bulb of the aorta appears to rise from both ventricles, immediately over the septum; and its division into two canals is complete on the seventh day. The pericardium is formed. Only two vascular arches arise on the left side of the aorta, but on

Fig. 284.

1, 2, 3. Heart of chick at the 45th, 65th, and 85th hours of incubation. After Dr. Allen Thomson. 4. Heart of a human embryo about the fifth week. After Von Baer. 1. Venous trunks. 2. Auricle. 3. Ventricle. 4. Bulbus arteriosus. *e, e.* Two aortic arches, which unite posteriorly to form the *aorta*. *g*. Auriculo-ventricular opening. *h*. Septum arising from the lowest part of the cavity of the ventricle. *i*. Inferior vena cava.

the right there are three. The latter, and the two anterior arches, are the chief divisions of the aorta, and receive the blood transmitted from the left ventricle. On the seventh day, the two posterior arches receive blood only from the right ventricle, and become the pulmonary arteries. At present, however, all the arches terminate in the descending aorta.

At this period, the course of the blood is as follows: From the system of the embryo it is carried by the *arteriæ vitellinæ*, or *omphalo-mesentericæ*, to the network of vessels of the vascular area, whence it passes to the sinus terminalis, which bounds the latter, and which, even on the fourth day, is found to be full of blood. The blood is returned to the heart by two anterior and two posterior venous trunks, arranged in pairs on each side of the median line of the body. The anterior pair are the *jugular veins*, and the posterior pair are the *cardinal veins*, which carry back the blood from the Wolffian bodies

and hinder parts of the embryo. Besides these trunks, however, there is a single one below, which receives the blood from the omphalo-mesenteric veins, and into this trunk the umbilical veins open subsequently. It becomes eventually converted into the *inferior vena cava*.

The pulsations of the heart commence before any cavity can be observed in the mass of embryonic cells of which it at first consists. Prevost and Lebert have observed the contractions before the development of any tissue distinctly muscular—a statement which we can confirm from observations upon the heart of the young field-snake (coluber natrix). Bischoff and Vogt also testify to the very early occurrence of pulsations.

In the human subject, about the fourth week, the septum between the ventricles commences to be formed. This is completed by the termination of the eighth week. The auricular septum, however, remains incomplete throughout fœtal life. The circulation in the fœtus, and the peculiarities of the fœtal heart, have been already described in page 677 of the present volume.

Aortic Arches.—In fishes, the vessel continuous with the bulbus arteriosus gives off on either side large branches, which are distributed to the gills; from these organs the blood is collected by small vessels, which ultimately reunite to form a large trunk corresponding to the aorta, which lies immediately in front of the spine. In the early embryos of all vertebrate animals, similar branches, called *aortic arches*, may be seen; and these unite at the back of the visceral cavity, to form the descending aorta. They are visible in the chick about the fortieth hour, according to Dr. Allen Thomson.

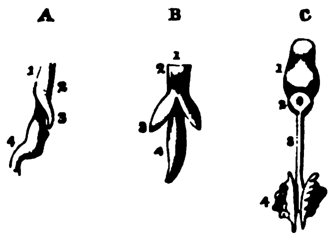
In birds there are at first six aortic arches; but, as development proceeds, the number becomes less. In mammalia the arches soon diminish to three. One becomes the arch of the aorta, and the other two are the *ductus arteriosi* of the pulmonary artery, of which the right soon disappears, so that at length only two arches remain—one from the right, and the other from the left ventricle. The anterior part of the arch from the former becomes the trunk of the pulmonary artery; while the cavity of the posterior portion (*ductus arteriosus*), which leads into the aorta, gradually becomes obliterated, and soon after birth nothing remains of it but a fibrous cord, between the aorta and pulmonary artery, which marks its original position throughout life.

Anterior Venous Trunks.—At an early period of development of the human embryo, the veins entering the heart from the upper part of the body are symmetrical; and in many of the lower animals they preserve this arrangement throughout life. As the development of the human embryo advances the large venous trunk on the left side diminishes, and subsequently disappears entirely, leaving the right trunk only as a persistent vessel. In a valuable paper published in the *Philosophical Transactions*, Mr. J. Marshall shows that the dilated portion of the coronary vein, the *coronary sinus*, is the persistent lower portion of the left anterior vein. It is interesting that in animals which have a left superior cava, the great cardiac coronary

vein opens into it. Even in the adult human heart there are certain structures which are obviously the remains of the upper portion of the left primitive venous trunk. These observations are very interesting, as they serve to explain certain unusual arrangements in the great anterior veins. Cases are recorded in which the two symmetrical trunks, usually only found at a very early period of development, remain persistent in the adult—an abnormal condition which receives explanation from the investigation of the nature of the early embryonic changes.

Development of the Lungs.—The lungs are first seen in the form of two small masses of cells, at the lower part of the œsophagus. These masses gradually increase in size, and a cavity is formed within. They coalesce at the upper part, which ultimately becomes the *trachea*. At this period of their development, the respiratory organs appear in the form of vesicles, appended to the lower part of the trachea.

Fig. 285.



Development of respiratory organs, showing origin of lungs from upper part of alimentary canal, after Rathke. A. Œsophagus of a chick on the fourth day of incubation. The rudiments of the trachea and lungs of the left side. 1. Inferior wall of the œsophagus; 2. Superior wall; 3. Rudimentary lung; 4. Stomach. B. The same seen from below. C. Tongue and respiratory organs of the embryo of a horse 1. Tongue; 2. Larynx; 3. Trachea; 4. Lungs seen from behind.

Reichert has shown that in the chick the lungs appear about the same time as the liver, and states, that although they seem to take their rise from the *membrana intermedia* (lying between the rudimentary nervous centres and the mucous membrane, p. 864), the upper portion of the visceral tube, according to his observations, is the real seat of their origin.

Thyroid Glands.—The first traces of the thyroid are observed in the chick between the sixth and seventh days as a small spherical mass of blastema on each side of the root of the neck. In structure the thyroid resembles that of the spleen. Professor Goodsir describes the thymus, thyroid, and supra-renal capsules as arising from the membrana intermedia; but Mr. Gray, on the other hand, has pointed out that they are formed from separate and independent masses of blastema.

The development of the *thymus* gland, and its subservience to respiration, have been already considered in p. 817.

Development of the Alimentary Canal.—The alimentary canal is first seen in the form of an elongated straight tube, in which oil globules may be distinguished. According to Reichert's observations on the embryo of the frog, the walls of the intestine appear to be formed originally from the most superficial cells of the yolk. The mucous membrane is developed from a thin layer of smaller cells of the yolk in the interior. Between the outer layer, which becomes converted into the muscular coat, and the inner layer, which constitutes the mucous membrane, a *glandular* layer is formed. From this tube the different parts are gradually evolved. The omphalo-

mesenteric duct is connected with the lower part of the small intestine, just previous to its junction with the large intestine. The

Fig. 286.

Embryo dog, showing the junction of the umbilical vesicle, with the intestinal canal. *a.* Nostrils. *b.* Eyes. *c.* First visceral arch. *d.* Second visceral arch. *e, f.* Right and left auricular appendage. *g, h.* Right and left ventricle of the heart. *i.* Aorta. *k.* Liver, between the two lobes of which is represented the divided omphalo-mesenteric vein. *l.* Stomach. *m.* Intestine, communicating with the umbilical vesicle by the omphalo-mesenteric duct. *n.* Umbilical vesicle. *o.* Wolffian bodies. *p.* Allantois. *q.* The upper extremities. *r.* The lower extremities. After Bischoff.

original connection with the umbilical vesicle is sometimes marked by an elongated pouch, or diverticulum, persistent in the adult. The original yolk-cells, contained in the cavity of the intestine, slowly disappear. The length of the small intestine gradually increases, until it assumes its mature form.

The stomach, at an early period, is not wider than the rest of the canal, and its limits are not to be distinguished.

Originally, the tube of the intestine is completely closed, both at the mouth and anus. The membrane is gradually removed, and an opening formed. In cases of *imperforate anus* there is no opening, in which condition an operation is necessary as soon as possible after birth.

Development of the Liver and Pancreas.—The precise mode of origin of the liver in the embryo has not yet been ascertained with certainty. Some observers hold that this large gland is originally formed upon a diverticulum of the intestine, while others have concluded that it is developed from a distinct and separate mass of blastema. In the chick, the first rudiment of this organ may be dis-

cerned between the fiftieth and sixtieth hour, and is described by Remak as consisting of two sets of cells—an external one, continuous with the external surface of the intestine, and an internal layer, composed of epithelium, and lining the sac, which ultimately becomes divided, so as to form ducts. From the epithelial lamina the columns of liver cells are formed; these extend into the outer lamina, branch and anastomose, and include in the meshes thus produced the cells of the outer surface, from which the vessels, nerves, and areolar tissue of the gland are developed.

Müller describes the liver as formed, on the fourth day of incubation, by a conical protrusion of the intestinal tube. The walls of the protrusion become very thick, and in their substance the ducts ramify.

According to Reichert, the liver and pancreas in the embryo frog are developed from a portion of yolk, which becomes separated from the general mass at a very early period, and is penetrated by a prolongation, posteriorly, of the vessel continuous with the cavity of the heart. At first there is no appearance of a division in this mass of yolk substance, which becomes separated from the remainder before any trace of the alimentary canal has manifested itself. Subsequently the two organs become more distinctly marked out. In the chick, according to the same observer, these organs are formed from a cellular growth upon the surface of the *membrana intermedia*, which is separated from the rest of this membrane. At first, the two lobes of the liver are of equal size, but, after a time, the right lobe preponderates, as it does in the adult.

Mr. Gray has figured the liver and pancreas of the chick. They seem to be developed from two separate protrusions of the intestinal tube, about the ninetieth hour of incubation. No vestige of the spleen is to be detected at this early period.

The following is Dr. Handfield Jones' account of the development of the liver in the chick. The parenchymatous portion is found to appear first; soon afterwards, an eminence, for which Dr. H. Jones proposes the name of *colliculus*, makes its appearance on the wall of that portion of the intestine which becomes the duodenum. From the latter tube pass two offsets to the liver; these, however, waste, but the *colliculus* remains. Subsequently, the cystic and hepatic ducts are developed close to the liver; they extend downwards, and open at the colliculus. In fishes and reptiles, the process of development is similar. Dr. H. Jones observes that, at one period, the gall-duct in tadpoles is lined by ciliated epithelium.

Reichert describes the formation of the columns of liver cells, and their increase in number; but he considers that the cells are not invested with basement membrane. This question has, however, been discussed in Chapter XXXIII.

Spleen.—Mr. Gray has demonstrated that the spleen arises in a fold of the intestinal laminæ about the 114th hour of incubation in the chick; and it is probable that in the human subject its formation takes place during the third or fourth week. It is quite distinct from the pancreas from the earliest period of development.

organs. As the latter gradually diminish in size, the development of the former advances.

Supra-renal Capsules.—The investigations of Mr. Gray upon the development of the supra-renal capsules in the chick, have proved that these bodies are not to be recognized before the end of the 7th day, when an ill-defined granular mass, of a reddish colour, makes its appearance between the aorta and upper and inner sides of the Wolffian bodies. It seems to have no connection with the thyroid or thymus, as Professor Goodsir described. Its minute structure resembled that of the spleen about the fifth day of incubation. By the 8th day, vesicles could be distinguished, and by the 14th day were found to contain oil globules, but no nuclei could be detected in their interior. The capsules were of large size, and of a yellow colour by the 18th day, and now the division into *cortical* and *medullary* portions was quite distinct. The supra-renal capsules are developed from two separate masses of blastema, situated between the aorta and upper and inner extremities of the Wolffian bodies. They have no connection with the latter, or with each other, and although in their minute structure they resemble the spleen, they arrive at their maximum of development before that organ.

Organs of Generation.—The sexual organs are developed at a later period than other glands. They are formed from masses of blastema situated upon the inner side of the upper and free part of the ducts of the Wolffian bodies. The ovaries and testicles are developed independently of the Wolffian bodies. At an early period of development the glands in both sexes have very similar characters, and it is not possible to say whether the organ is ultimately to become converted into a testicle, or whether it is to retain its primitive characters, which agree with those of the ovary. According to the observations of Valentin, the ovary of mammalian animals is developed in the form of tubes, in which the Graafian follicles are produced.

The *excretory ducts* in the lowest vertebrata are two in number, and open into the cloaca, an arrangement which is persistent in many fishes, but in the higher classes they are united, and form a single canal, the arrangement of which has been carefully investigated by Müller. From this canal, in the male, is formed the *Weberian organ*, or *uterus masculinus*, while in the female it gives origin to the *uterus* and *vagina*.

The upper part of the excretory duct of the Wolffian bodies in the male, becomes much modified in character, and is ultimately converted into the *epididymis*, whilst the lower portion becomes the *vas deferens*.

The lower part of the urino-genital canal, which becomes converted into the external organs of generation, for some time presents a cleft or fissure on its inferior surface, which in male reptiles and birds remains open throughout life, but in mammalia becomes converted into a canal, which extends to the tip of the *penis* in the male, or along the under surface of the *clitoris* in the female. Sometimes, however, a portion remains open, and the wall of the urethra is de-

ficient in its anterior part below, when the congenital deformity known as *hypospadias* results. The folds of skin which bound the furrow, ultimately become converted into the scrotum of the male, or labia of the female. The testicles descend into the cavity of the scrotum about the eighth month, but not unfrequently are retained within the abdominal cavity.

The authors would refer particularly to the following works with reference to the subjects discussed in the present chapter: Müller's Physiology; Rathke, Beiträge zur Geschichte der Thierwelt; Valentin, Entwickelungs-Geschichte; Dr. Handfield Jones on the Structure and Development of the Liver, Phil. Trans., 1849; Victor Carus' System der Thierischen Morphologie; Reichert, das Entwickelungsleben im Wirbelthier-Reich; Mr. Marshall's paper On the Development of the great Anterior Veins in Man and Mammalia, Phil. Trans., 1850; Mr. Gray's papers On the Development of the ductless Glands in the Chick, Phil. Trans., 1852; and his paper on the development of the retina and optic nerve, and of the membranous labyrinth and auditory nerve, Phil. Trans., 1850.

CHAPTER XLIII.

OF THE MEMBRANES OF THE FŒTUS.—OF THE STRUCTURE OF THE CHORION.—OF THE AMNION.—LIQUOR AMNII.—OF THE UMBILICAL VESICLE.—OF THE ALLANTOIS.—ALLANTOIC FLUID.—UMBILICAL CORD.—BIRTH.

Formation of the Placenta.—The early development of the chorion has been described in a former page. At first, the villi are composed entirely of cells, invested on their external surface with a very delicate structureless membrane; but after the vessels, conducted by the allantois, have reached its inner surface, vascular loops are prolonged into them. Bischoff considers that in the human ovum, and in that of the bitch, which are destitute of an albuminous covering, the tufts are formed directly from the zona pellucida alone.

In two orders of mammalia, the *marsupialia* and the *monotremata*, there is no connection between the vascular system of the mother and that of the fœtus, which is nourished from a very early period with milk.

The relation between the blood of the fœtus and that of the mother is nearly the same in all placental mammalia. The wall of the maternal vessels—a layer composed of cells from the modified mucous membrane of the uterus—and another cellular layer belonging to the fœtal tuft, always separate them; but in the greater number of mammalia, the fœtal tufts come into relation with the *capillary vessels* of the mother: while in *man* they are in contact with the walls of a *large cavity* containing blood.

The mode of arrangement of the tufts, or, in other words, the form which the placenta assumes, is very different in the various mammalia. Sometimes the whole chorion is covered with villi, as in the *pachydermata* (hog, elephant, etc.); sometimes these form little collections or cotyledons, as in the greater number of *ruminants* (sheep, ox, goat, etc.); sometimes they form a band encircling the central portion of the chorion, as in the *carnivora;* and in some instances they are confined to one single part, forming a single placenta, as in the *rodentia*, and also in the *human subject* (vide figs. 280, 292).

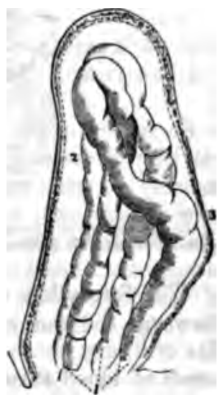
The beautiful branched and highly complicated conical *fœtal villi* of the ruminant dip into deep recesses in the *maternal cotyledons*, upon the walls of which the maternal

capillary vessels are spread out; while the vascular loops of the human fœtus, as was shown by Professor Weber, dip into the dilated vessels of the mother, which become large venous sinuses, and are thus completely bathed on all sides by the mother's blood.

The villi increase very much in number and complexity in that part of the chorion which is to become the placenta; while on other parts of the surface they retain the same characters as at a very early stage. Each villus contains a vascular loop, which is directly continuous with the umbilical vessels of the fœtus; and the whole of the blood of the fœtus is made to pass through the vessels in the tufts by the forces of the fœtal circulation. The cells of which the villi were entirely composed, at a very early period diminish in number; but still several remain towards the apex.

During this time, the soft membrana decidua has been increasing in thickness and vascularity. Its capillary vessels become enormously increased in diameter, and ultimately form small pouches or sinuses containing blood. The fœtal tufts come into close relation with the walls of these sinuses, but are still separated by a thin layer of the cellular decidua, and project into their interior, being of course invested with the wall of the sinus, just as the viscera are covered with peritoneum. Such is the relation of the bloodvessels of the fœtal placenta to those of the mother, according to the observations of Dr. J. Reid, Weber, and Goodsir. The structures, therefore, which intervene between the blood of the fœtus and that of the mother, are the following: the walls of the fœtal capillaries; the cells at the extremity of the fœtal tufts; the delicate investing membrane covering these; a thin stratum of fluid separating the maternal and fœtal portions of the placenta, and containing not only the materials for absorption, but any substances to be removed from the fœtal blood; the cells of the membrana decidua; and, lastly, the wall of the venous sinus, into which the fœtal tuft projects.

Fig. 287.



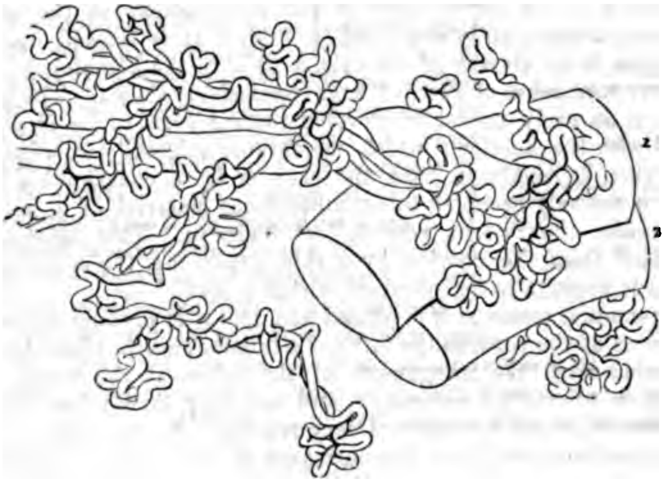
Extremity of a villus, showing capillary vessels. After Weber.

The cells upon the surface of the villus form little groups, and appear to radiate, as it were, from the centre of each collection. This central point, Professor Goodsir regards in the light of a *germinal spot or nutritive centre*, which supplies successive generations of cells as the old ones are gradually removed.

The wall of the venous sinus of the mother, reflected from tuft to tuft, forms numerous tubular processes, passing in various directions amongst them; thus connecting the several tufts with each other, and forming a sort of supporting framework for the entire organ. The tubular prolongations, of course, contain cells of the decidua in their interior, and by their outer surface are continuous with the lining membrane of the venous sinuses of the mother. Dr. J. Reid has shown that the fœtal tufts often dip quite into the uterine sinuses.

has been looked upon by many pathologists as of a morbid nature, and has been brought forward as one of the causes of abortion; but

Fig. 290.



Villi of the fœtal portion of a placenta; after E. H. Weber. 1. Vein. 2. Artery. Magnified 100 diameters.

the observations of our friend, Dr. Druitt,* and others, show that fatty degeneration of the vessels occurs in the great majority of placentæ which are subjected to examination, although in some it is much more advanced than it is in others. It occurs first in those tufts situated at the circumference of the placenta, in which part the functions of the organ cease first. In numerous instances, also, small masses of earthy phosphates are found in the fœtal tufts. Although fatty degeneration is doubtless to be regarded, in many instances, as a morbid alteration, we must at the same time bear in mind, that it does occur as a normal process, and is one of the changes which ensues in tissues prior to their absorption, after the period of their functional activity is brought to a close. It seems to be one of the first of a series of changes which ends in the removal of the tissue, or in the complete disappearance of its ordinary characters.

From what we have already said with reference to the structure of the human decidua and placenta, it follows, that both are separated at birth, and must be renewed at each successive pregnancy. Both the uterine and fœtal portions of the placenta are removed, and of course a considerable lesion takes place at the time. The great uterine veins are torn across, and the violent contraction of the uterus alone prevents the death of the mother from hemorrhage at each period of parturition. Should the uterus, from any cause, fail to contract, the death of the mother from hemorrhage is inevitable, as the experience of almost every practitioner but too clearly proves.

* Medico-Chir. Trans., vol. xxxvi.

Such a result, however, would not happen in the ruminants, and in some other animals, where the fœtal tufts are readily withdrawn from the maternal sheaths, which merely contract after parturition, and become much smaller, but suffer no lesion whatever.

Amnion.—The early stages of the development of the amnion have been already fully described (p. 866). It is formed upon the same plan in all classes of animals, as it is in the human subject, as the later researches of Bischoff have conclusively shown. The human ovum, at an early period of development, is seen to be closely invested with the amnion; which membrane, originally consisting of two layers, is separated from the chorion by a considerable space, which is entirely occupied by an albuminous material of a jelly-like consistence, the "corps reticulé" of Velpeau. This substance is separated from the chorion by a thin membrane, the *endochorion;* so that it appears to be contained within a special sac.

The amnion consists of a closed sac, and it is prolonged over the structures of the cord, in the form of a tubular sheath, which becomes continuous with the integument of the fœtus at the navel. The amnion is tolerably transparent, and not very thick; but often so firm, that it cannot be ruptured very readily. No vessels, nerves, or lymphatics have yet been demonstrated in the healthy membrane; but in some cases of disease it has been found to be highly vascular. M. Coste speaks of the amnion as the "epidermis of the blastoderma."

The sac of the amnion contains a considerable quantity of an albuminous fluid, the *liquor amnii*, which, according to Vogt, consists of common salt, lactate of soda, albumen, and sulphate and phosphate of lime. Dr. G. O. Rees has found urea in the liquor amnii, and the presence of this substance has been confirmed by other observers. The liquor amnii, at three and a half months, had a specific gravity of 1·0182, and contained 10·77 of albumen in 1000 parts; and at six months its specific gravity was 1·0092, and it contained only 6·67 parts of albumen per 1000.

Liquor Amnii.—The liquor amnii enters the mouth of the fœtus, and no doubt passes into the *trachea* as well as the *stomach*; but the amount of nutrition which the fœtus receives from this source, must indeed be small. At the same time, it is interesting to observe that the composition of the liquor amnii varies at different periods of pregnancy, as has been shown by Vogt; and during the earlier periods of gestation, the quantity of chloride of sodium is much greater than during the latter part of the time. The proportion of this substance appears to be greater at that period of the development of the embryo, when cell-multiplication and growth is most active.

Dr. Beale has made, for Dr. A. Farre, an examination of liquor amnii at the eighth month, taken from the body of a woman who died at this period of gestation. The fluid was of a very pale straw colour, slightly turbid, and contained flocculi suspended in it. It was quite limpid, and readily dropped from a tube. It was very feebly acid, and remained so for several days after it had been removed. The deposit was subjected to microscopical examination, and found to contain many epithelial cells and oil-globules from the *vernix*

caseosa, the soft oily coating with which the skin of the fœtus becomes covered in the later months of pregnancy. Besides these, there were several clear, transparent, elongated cylindrical bodies, evidently *casts of the uriniferous tubes* of the kidney of the fœtus. This observation proves, very satisfactorily, that the urinary secretion becomes mixed with the liquor amnii in the human subject.

The specific gravity of this specimen was 1009·2 and it contained in 1000 parts—

		In 100 parts solid matter.
Water	982·00	
Solid matter	18·00	
Organic matter soluble in water	6·11	33·94
Fixed alkaline salts	8·09	44·94
Albumen, earthy salts, and fatty matter .	3·80	21·11

Dr. Prout found sugar of milk in the liquor amnii of a cow, at an early period of pregnancy.

Umbilical Vesicle.—We have alluded to the mode of formation of the umbilical vesicle in page 866. Our friend, Mr. Grainger, has made some very important observations on its minute structure and functions in the chick. At a very early period, the lining membrane of the umbilical vesicle presents the appearance of a highly organized mucous membrane, the surface of which is perfectly smooth. After a time, a number of folds, which were termed "valves" by Haller, make their appearance. By the ninth day, these are considerably developed, and project into the yolk. The folds become more complicated and numerous; and by the nineteenth day, are as much as $\frac{5}{12}$ths of an inch in depth in the deepest part. Upon the folds, and in the intervals between them, grayish-white corpuscles are very numerous. Mr. Dalrymple has shown that these cells may be washed away from the vessels beneath, of which he has made very beautiful injections. The yellow appearance of the vessels, whence they have been called *vasa lutea* by Haller, is due to their being entirely covered with these yellowish corpuscles. The surfaces of the folds of the membrane are highly vascular, and the majority of the capillaries spread out upon them are probably venous. Thus the surface of the umbilical vesicle is enormously increased in extent, in a manner precisely similar to that in which the mucous membrane of the intestines is extended by the arrangement of the valvulæ conniventes. Such is the character of the vascular surface by which all the nutritive constituents of the yolk are absorbed, which are afterwards carried to the system of the chick for its nutrition, throughout the whole period of development within the shell. That portion of the yolk nearest to the vessels becomes quite fluid, and is

Fig. 291.

Folds of the vitellary membrane and vasa lutea (after Mr. Dalrymple), showing arrangement of the vessels. From the chick.

therefore in a state most favourable for absorption; it also becomes mixed with the albumen, by which it was originally surrounded, and which enters by endosmosis through the yolk-membrane; and it undergoes certain chemical changes, as the experiments of Dr. Prout have shown.

We have already shown (page 866) that the yolk is in direct continuity with the cavity of the intestine, through the intervention of the vitelline duct; and it is therefore possible for the nutrient material to reach the system of the chick, by this shorter and more simple course, at a very early period of development. Although there can be no doubt of the existence of this tubular communication at one time, it is nevertheless quite certain that, throughout the greater part of the period of incubation, the duct is impervious, and the nutrient material of the yolk is absorbed by the vessels ramifying upon the surface of the umbilical vesicle, and is carried, by the omphalo-mesenteric vessels, to the vascular system of the embryo in the manner above described.

The yolk-sac of the *mammalian ovum* has a structure very similar to that of the bird. The communication with the intestine is at first very wide, but soon becomes reduced to a narrow tube, the *omphalo-mesenteric or vitelline duct*. The umbilical vesicle generally disappears at a very early period; and in the embryo calf, not more than six lines in length, according to Bischoff, it is only connected with the embryo by a thread-like pedicle, and is of very small size. In the frog it disappears very early, while in carnivorous animals, and also in the rodents, it remains throughout a considerable period of intra-uterine life, and is very highly vascular.

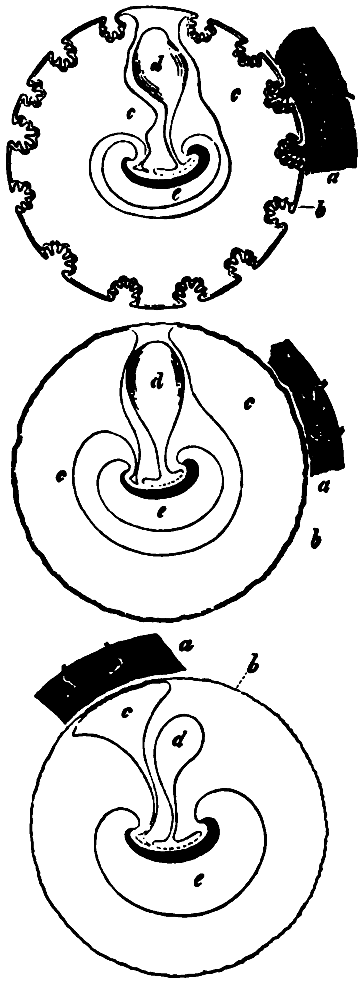
The vessels of the umbilical vesicle are well shown in an embryo of Dr. Sharpey's. The fœtus was $1\frac{1}{20}$ of an inch in length. The vesicle was $\frac{4}{10}$ of an inch in diameter, and the pedicle $\frac{7}{15}$ of an inch long. A beautiful engraving of this embryo will be found in *Müller's Physiology*, translated by Dr. Baly.

In the human embryo of from two to three lines in length, Müller found the duct of the umbilical vesicle very short and wide, and was able to trace its walls in direct continuity with those of the intestine. Dr. Allen Thomson also testifies to the same fact, and Weber has delineated its bloodvessels. It is very distinct in the human embryo about the twentieth day. It lies between the chorion and amnion, and is filled with a yellowish-white yolk. By the third month, it is about four or five lines in diameter; and from this time it becomes smaller, and gradually disappears. Mayer has, however, detected both the vesicle and its thread-like pedicle at the full period of gestation.

Development of the Allantois.—At a very early period of development of the mammalian embryo, a collection of cells makes its appearance upon the anterior surface of its caudal extremity. This gradually increases in size, becomes flask-shaped, and a cavity in the interior of the mass becomes visible. The vesicle thus formed rapidly enlarges. It contains fluid, and upon its surface, vessels, which ultimately become the *umbilical vessels*, are seen ramifying. As it

grows, these vessels are carried with it towards the inner surface of the chorion. The vessels of the umbilical vesicle waste with this structure, while those conducted to the placenta by the allantois, ultimately become the *two umbilical arteries* and the umbilical vein. In the human embryo, the chief office of the allantois seems to be that of conducting the vessels towards that portion of the chorion which is to become the future *placenta;* and as soon as the connection between the fœtus and the placenta is established, which in the human embryo takes place between the third and fourth weeks, the allantois is no longer distinguishable. Besides this office, however, the allantois receives the secretion from the temporary kidneys, or corpora Wolffiana, previous to the formation of the permanent structures.

Fig. 292.



Diagrams to show the arrangement of the allantois, and the formation of the placenta in different classes of animals:—

a. A portion of the wall of the uterus. *b.* Chorion. *c.* Allantois. *d.* Umbilical vesicle. *e.* Amnion.

A. In ruminants. The cotyledons, spread out over the internal surface of the uterus, fit into cup-shaped cavities formed by the altered chorion. The allantois is of a very large size, and entirely surrounds the embryo.

B. In the feræ (cat, etc.), the placenta forms a zone which surrounds the embryo like a ring. There are no cotyledons.

C. In rodentia and in the human subject. The placenta is limited to one particular part of the chorion. The allantois is very small, and only distinguished at a very early stage.

In many of the lower animals, however, the allantois is developed to a much greater extent than it is in man. In birds, and in several mammalian orders, it forms a very large sac, which completely surrounds the embryo; and in the ruminants, it contains many quarts of fluid, towards the termination of intra-uterine life.

The allantois in the chick is readily distinguished before the close of the third day, and appears to be connected with the terminal portion of the intestine. Reichert has carefully investigated its development, and has shown that it is not developed from the intestine or from the *membrana intermedia*, but arises from two masses of cells, situated at the posterior extremity of the Wolffian bodies, which afterwards coalesce, forming a pear-shaped mass, in which a cavity soon manifests itself. Passing from the Wolffian bodies to the two small masses above referred to, are two lines or threads, which ultimately become the excretory ducts of the former organs.

At an early period, the allantois communicates with a common cavity, or cloaca, into which the ureters, the excretory ducts of the Wolffian bodies, and those of the organs of generation open. This is called the *sinus urino-genitalis*. The allantois grows very rapidly, and ultimately entirely envelops the embryo with its amnion and yolk, and becomes applied to the inner surface of the

membrane of the egg-shell. It is highly vascular, and is, in fact, the respiratory organ of the chick as long as it remains within the shell.

The arrangement of the capillaries has been investigated by our friend, the late Mr. Dalrymple, who has made some very successful injections of the allantois of the chick. On the outer surface (that which is in immediate contact with the membrane of the shell), the capillaries are exceedingly abundant and very minute. Mr. Dalrymple compares their arrangement to that of the vessels in the air-cells of the lung of reptiles—a resemblance of great interest, when we consider that in the bird this membrane performs a most important part in aerating the blood; indeed, it is through the intervention of the allantois that all the respiratory changes taking place in the chick are carried on. The air passes through the pores in the shell and membrane beneath, and thus is brought into contact with the blood ramifying in the vessels of the allantois.

The allantois, as was shown by Reichert and others, is connected with the efferent ducts of the Wolffian bodies, and receives the secretion from these glands.

In the human subject, soon after its formation, a dilatation is observed in that part of the allantois nearest the fœtus. This is the rudiment of the *urinary bladder*. Just at the junction between the vesicular portion and the straight tube which passes from this point to the chorion, a folding or constriction occurs. This indicates the first formation of the *urachus*, which has been erroneously considered to be situated in that part between the vesicle and the fœtus. This latter portion, however, soon becomes divided into two tubes, one being connected with each Wolffian body. These tubes are ultimately converted into the ureters. The ureters and urinary bladder are gradually drawn into the cavity of the pelvis, through the umbilical opening. This process, according to Langenbeck, is completed between the twelfth and twentieth week. The urachus, between the bladder and umbilicus, remains tubular long after this, and even at birth in some few instances; in which cases urine has been known to escape from the umbilicus.

Fig. 293.

Diagram of uterus, with a fully formed, but very young ovum. *a*. Plug of mucus occupying cervix uteri. *b*. Opening of Fallopian tube. *c*. Decidua vera. *d*. Cavity of uterus, nearly filled with ovum. *e*. Decidua reflexa. *k*. Chorion. *f*. Decidua serotina. *g*. Allantois in situation of placenta. *i*. Amnion. *h*. Umbilical vesicle. 11. Umbilical cord. 12. Space between chorion and amnion, filled with albuminous matter.

Allantoic Fluid is clear, of a brownish yellow colour. Its specific

gravity varies from 1005 to 1030. It contains alkaline lactates, extractive matters, and ammoniacal salts, with alkaline and earthy phosphates, and chloride of sodium. Besides these, however, there is a definite crystallizable substance peculiar to this fluid, termed *allantoin*, which is closely related to *uric acid;* indeed, it may be prepared artificially from this substance, while *urea* is produced at the same time. The composition of allantoic fluid seems nearly identical with that of the urine of calves while suckling, at which time it contains no hippuric acid. This latter substance, however, makes its appearance in the urine as soon as the animal takes vegetable food. *Uric acid* has been found in the allantoic fluid of birds by Jacobson.

Velpeau held that the allantois completely surrounded the human embryo, as it does in many animals; but this statement has been completely refuted by the researches of Müller, Bischoff, Langenbeck, and others.

Umbilical Cord.—The umbilical cord is the long, narrow pedicle, contained in a tube of the amnion, which connects the fœtus with the placenta. In the advanced embryo, it consists principally of the large vessels, through the intervention of which all the nutrient material absorbed from the blood of the mother is conducted to the system of the fœtus.

At an earlier period of development, the cord is really composed of—

1. The remains of the omphalo-enteric duct, or pedicle of the umbilical vesicle.
2. The vasa omphalo-meseraica, or branches of the mesenteric vessels of the fœtus.
3. The urachus, and all that remains of the allantois.
4. The umbilical vessels; consisting of one umbilical vein, which brings the blood back *from* the placenta, and two umbilical arteries, by which the blood is carried *to* the placenta.

In animals generally, however, there are two veins, as well as two arteries, which are the chief branches of the hypogastric arteries of the fœtus. The circulation of the fœtus has been fully described in page 677.

Birth.—In the human subject, the period of pregnancy lasts about nine solar, or ten lunar months, or 280 days. It varies, however, within certain limits.

The phenomena of parturition are specially treated of in works on Midwifery; so that a very brief reference to this part of the subject will only be required.

Of the immediate cause of the contraction of the uterus, little is known. Valentin attributes it to the excitement of the organs which always exists at the menstrual periods; and he considers that parturition takes place at the tenth menstrual period. Dr. Tyler Smith has advocated a similar view, and believes that the contractions of the uterus are due to the increased action of the ovaries operating upon the cord through the ovarian nerves, which act as *excitors;* while the uterus is thrown into contraction through the medium of

the uterine nerves, which are therefore to be regarded as the motor nerves concerned in this *reflex* action. The action of the uterus is no doubt in part due to the stimulus produced by the increasing bulk of its contents.

The foetus lies in utero with its head downwards during the later months of pregnancy. The contraction of the thick muscular walls of the uterus tends to force the head upon the os uteri, in consequence of which the circular fibres of the latter gradually relax, and the opening dilates. The membranes are pressed towards the vagina, and protrude through the os, until at length they burst, and the liquor amnii escapes.

At each successive pain, the child's head is forced lower and lower into the vagina. The pains increase in force and frequency, and the uterine contractions are assisted by the voluntary contractions of the abdominal muscles; until at last, in a violent paroxysm of pain, the head is born, and the remainder of the child very quickly follows.

A little hemorrhage usually occurs immediately after the birth of the child, in consequence of the partial detachment of the placenta. This is followed, however, by contractions; and the placenta itself is forced into the vagina shortly after the birth of the child. With the placenta are also expelled portions of the membrana decidua, the remains of the chorion, and the amnion.

After labour, a considerable quantity of fetid discharge takes place from the uterus. At first, this is composed principally of blood; but afterwards it becomes paler, and consists chiefly of mucus, with pus corpuscles, and a certain quantity of fluid exudation. The uterus gradually returns to its former volume.

For information upon the questions discussed in the present chapter, the student is referred to the works previously enumerated.

CHAPTER XLIV.

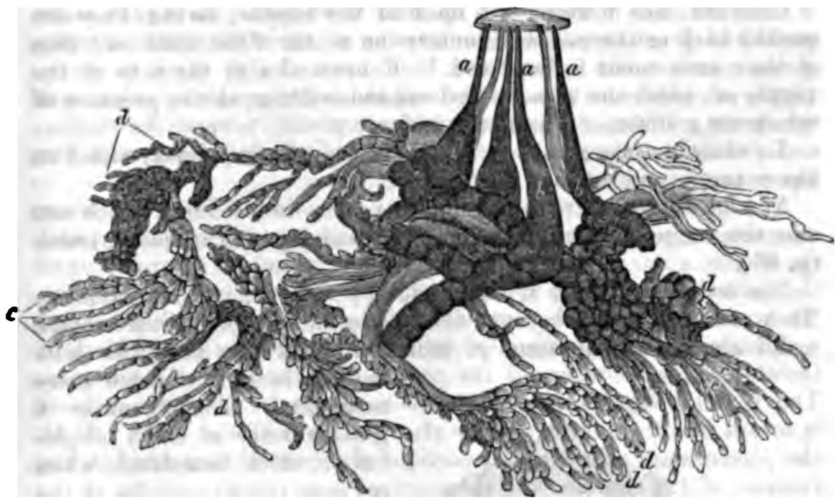
OF LACTATION.—THE LACTEAL GLANDS.—NIPPLE.—MINUTE STRUCTURE OF THE GLAND.—BLOODVESSELS.—ABSORBENTS.—MILK.

The *Lacteal Glands* are two large, symmetrical organs, which are only fully developed in the female. In the male, however, they exist in a very rudimentary state. During the later half of pregnancy, the lacteal glands increase very much in size; and about the period of parturition, they begin to secrete milk. They are racemose glands, and are ultimately composed of numerous roundish follicles, arranged round the terminal extremities of the ducts.

The structure of the lacteal glands formed the subject of a very important investigation by Sir Astley Cooper.

The lacteal tubes are about twenty in number, and terminate at the extremity of the nipple, by as many orifices. The ducts are

Fig. 294.



Preparation with six milk-tubes injected from the nipple, by Sir Astley Cooper.—*a.* The straight or mammillary tubes, proceeding from the apex of the nipple. *b.* Reservoirs or dilatations of the ducts. *c.* Branches of the mammary ducts. *d.* Glandules.

dilated as they approach the nipple, and the dilatations are called *reservoirs.* In the human subject, these are very small; but in the cow, they are large enough to hold a quart.

The *nipple* is surrounded by a dark coloured circle, termed the *areola*, smooth in the child, but slightly tuberculated at the period of puberty. In the child it is about half an inch in diameter; but in the adult, about an inch; while during lactation, it increases to two inches. After impregnation, it changes from its reddish colour to a dark brown.

A secretion is poured out from the mucous follicles, which lubricates the skin about the nipple.

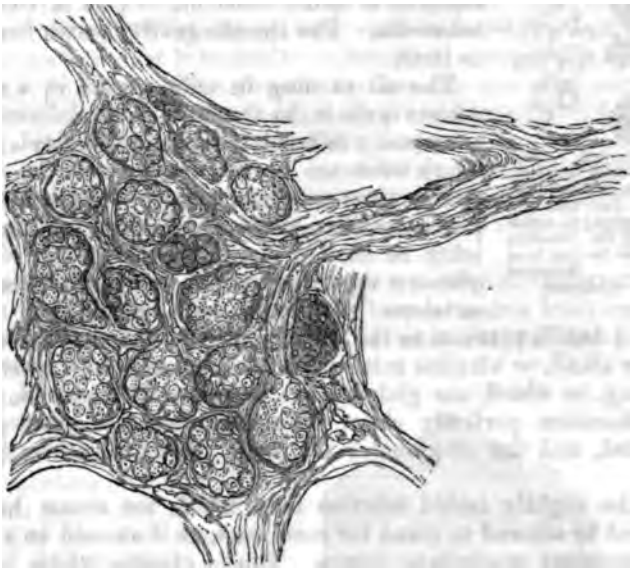
The terminal follicles of the gland were injected by Mascagni; but for almost all that we know of the minute anatomy of the breast, we are indebted to the beautiful researches of Sir Astley Cooper, published in 1840.

The surface of the breasts, in the unimpregnated state, is smooth and compact; but as pregnancy advances, they become uneven, in consequence of the distension of the follicles with secretion.

The nipple, before puberty, forms an almost smooth conical eminence; but in lactation it becomes flattened, so that its extremity becomes the broader part, and thus it is more readily held by the child's mouth. Its characters have been minutely described by Sir Astley Cooper: "At sixteen years it is slightly wrinkled; at seventeen, it has small papillæ upon its surface; from twenty to forty years, the papillæ are large; from forty to fifty, the nipple becomes

instances, they have been unusually developed; and instances are even on record, where milk has been secreted by the lacteal gland

Fig. 296.

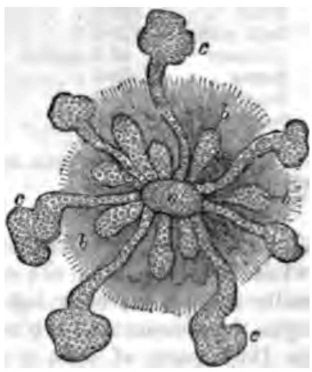


Terminal follicles of the lacteal gland, with ducts, from a woman who was not pregnant. The fibres of yellow elastic tissue are numerous upon the wall of the duct. The terminal follicles are separated from each other by a considerable quantity of areolar tissue. Magnified about 150 diameters.

of the male; indeed it has been related by Humboldt, that the infant has been nourished by the male parent after the death of the female.

The lacteal glands are developed like other glands connected with the skin. In the fourth or fifth month, according to the observations of Langer and Kölliker, a papillary projection of the mucous layer of the epidermis occurs. This increases in size; and, by the sixth or seventh month, throws off a number of offsets, from which the lobes of the gland are gradually formed.

Fig. 297.

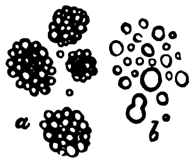


Lacteal gland of a newly-born child. The rudimentary follicles are well shown. After Langer.

Milk is white and opaque, from the presence of numerous oil-globules. Besides these, which are held in suspension, and are insoluble, milk contains numerous nutritious substances which exist dissolved in the fluid. After it has been allowed to stand for some time, the oil-globules rise to the surface, by reason of their lightness, forming the cream.

Milk usually does not obtain its normal characters until three or four days after delivery. The first proportion, which is secreted before parturition, is thinner, and contains but a quantity of saccharine and oily materials. In it albumen is often detected. This is called the *colostrum*. The specific gravity varies from 1020 to 1045.

Fig. 298.



a. Colostrum corpuscles. b. Milk globules. In the lower part of the figure, two are seen running together, in consequence of the investing membrane having been dissolved. Magnified about 215 diameters.

The oil existing in milk, occurs in a state of minute division, in the form of oil-globules, which are equally diffused throughout the fluid. These oil-globules are each invested with a delicate membranous envelope, composed of caseine, which prevents their running together. If milk and ether be shaken and well mixed, the oily constituents are not dissolved, in consequence of the envelope of caseine with which they are invested; but if, previous to the addition of the ether, a little acetic acid or alkali, or alkaline salt, which has the power of dissolving the covering, be added, the globules are immediately dissolved, and the milk becomes perfectly clear. By *churning*, the envelopes are ruptured, and the oil-globules are made to run together, forming *butter*.

If the slightly turbid solution from which the cream has been removed be allowed to stand for some time, or if an acid be added to it, a flocculent precipitate occurs. This is caseine, which is coagulated by all acids. It is, however, not coagulated by heat; but during evaporation, a scum forms upon the surface of solutions containing caseine.

The following analyses show the chemical composition of human milk. Specific gravity, 1030—1034.

	Colostrum.	4 days after parturition.	9 days.	12 days.	Average.
Water	828·0	879·848	885·818	905·809	891·0
Solid matter	172·0	120·152	114·182	94·191	109·0
Albumen	40·0 caseine	35·333	36·912	29·111	33·7
Butter	50·0	42·968	35·316	33·454	37·1
Sugar of milk	70·0	41·135	42·979	31·537	38·5
Salts	3·1	2·095	1·691	1·939	1·9

The first two analyses are by Franz Simon, and the last three by Clemm.

Cow's milk contains more caseine and less sugar than human milk. Ass's milk contains less butter and less caseine, but more sugar: while in goat's milk the caseine preponderates over the other constituents. L'Heretier has shown that temperament exerts an influ- upon the character of the milk. The average quantity of solid matter in 1000 parts of milk from fair women, was 120 grains; and of brunettes, as much as 134 grains.

The characters of the milk, also, it need hardly be said, are much influenced by the health and diet of the mother, and by the age of the infant. At first, the caseine is small in quantity, and gradually increases up to its normal standard; while, on the other hand, the

proportion of sugar is very large at first, and subsequently diminishes in quantity. The proportion of butter varies considerably. Phosphate of lime is very soluble in solutions of caseine, and in this way, no doubt, is introduced into the system of the young animal.

In disease, the milk may contain blood, pus, or mucus, and occasionally lactic acid and albumen have been detected in it; urea and bile-pigment have also been found in milk.

Upon the subject of lactation, the student may refer to the following: On the Anatomy of the Breast, by Sir Astley Cooper, 1839. C. Langer, Ueber den Bau und die Entwicklung der Milchdrüsen, mit 8 Taf., Denkschr. d. Wiener Akad. Bd. iii. Wien. 1851. Article "Mammary Gland," by Mr. Solly, in the Cyclopædia of Anatomy and Physiology. And Simon's Animal Chemistry, translated by the Sydenham Society.

INDEX.

BLANCHARD & LEA'S
MEDICAL AND SURGICAL PUBLICATIONS.

TO THE MEDICAL PROFESSION.

In the present catalogue we have affixed prices to our publications, in obedience the repeated requests of numerous members of the profession. While books, ce all other articles, must necessarily vary somewhat in cost throughout the ex- nded territories of this country, yet our publications will generally be furnished these rates by booksellers throughout the Union, who can readily and speedily ocure any which they may not have on hand.

To accommodate those physicians who have not convenient access to bookstores, who cannot order through merchants visiting the larger cities, we will forward ır works by mail, *free of postage*, on receipt of the printed prices in current funds postage stamps. As our business is wholesale, and we open accounts with book- llers only, the amount must in every case, without exception, accompany the der, and we can assume no risks of the mail, either on the money or the books; d as we only sell our own publications, we can supply no others. Physicians ll, therefore, see the convenience and advantage of making their purchases, when- er practicable, from the nearest bookseller.

We can only add that no exertions are spared to merit a continuance of the atifying confidence hitherto manifested by the profession in all works bearing our ıprint.

BLANCHARD & LEA.

PHILADELPHIA, April, 1858.

*** We have now ready a new ILLUSTRATED CATALOGUE of our Medical and ientific Publications, forming an octavo pamphlet of 80 large pages, containing ecimens of illustrations, notices of the medical press, &c. &c. It has been pre- red without regard to expense, and will be found one of the handsomest specimens typographical execution as yet presented in this country. Copies will be sent to y address, by mail, free of postage, on receipt of nine cents in stamps.

Catalogues of our numerous publications in miscellaneous and educational litera- re forwarded on application.

TWO MEDICAL PERIODICALS, FREE OF POSTAGE,
FOR FIVE DOLLARS PER ANNUM.

HE AMERICAN JOURNAL OF THE MEDICAL SCIENCES, subject to postage, when not paid for in advance, - - - - - - - - -	$5 00
HE MEDICAL NEWS AND LIBRARY, invariably in advance, - -	1 00

or, BOTH PERIODICALS furnished, FREE OF POSTAGE, for Five Dollars remitted in advance.

THE AMERICAN JOURNAL OF THE MEDICAL SCIENCES,
EDITED BY ISAAC HAYS, M. D.,

published Quarterly, on the first of January, April, July, and October. Each number contains least two hundred and eighty large octavo pages, handsomely and appropriately illustrated, erever necessary. It has now been issued regularly for more than THIRTY-FIVE years, and it has n under the control of the present editor for more than a quarter of a century. Throughout s long period, it has maintained its position in the highest rank of medical periodicals both at home d abroad, and has received the cordial support of the entire profession in this country. Its list of llaborators will be found to contain a large number of the most distinguished names of the pro- sion in every section of the United States, rendering the department devoted to

ORIGINAL COMMUNICATIONS

l of varied and important matter, of great interest to all practitioners.

As the aim of the Journal, however, is to combine the advantages presented by all the different rieties of periodicals, in its

ALLEN (J. M.), M. D.,
Professor of Anatomy in the Pennsylvania Medical College, &c.

THE PRACTICAL ANATOMIST; or, The Student's Guide in the Dissecting-ROOM. With 266 illustrations. In one handsome royal 12mo. volume, of over 600 pages, leather. $2 25. (*Just Issued.*)

In the arrangement of this work, the author has endeavored to present a complete and thorough course of dissections in a clearer and more available form for practical use, than has as yet been accomplished. The chapters follow each other in the order in which dissections are usually conducted in this country, and as each region is taken up, every detail regarding it is fully described and illustrated, so that the student is not interrupted in his labors, by the necessity of referring from one portion of the volume to another.

However valuable may be the "Dissector's Guides" which we, of late, have had occasion to notice, we feel confident that the work of Dr. Allen is superior to any of them. We believe with the author, that none is so fully illustrated as this, and the arrangement of the work is such as to facilitate the labors of the student in acquiring a thorough practical knowledge of Anatomy. We most cordially recommend it to their attention.—*Western Lancet*, Dec. 1856.

We believe it to be one of the most useful works upon the subject ever written. It is handsomely illustrated, well printed, and will be found of convenient size for use in the dissecting-room.—*Med. Examiner*, Dec. 1856.

From Prof. J. S. Davis, University of Va.

I am not acquainted with any work that attains so fully the object which it proposes.

From C. P. Fanner, M. D., Demonstrator, University of Michigan.

I have examined the work briefly, but even this examination has convinced me that it is an excellent guide for the Dissector. Its illustrations are beautiful, and more than I have seen in a work of this kind. I shall take great pleasure in recommending it to my classes as *the text-book of the dissecting-room.*

ANALYTICAL COMPENDIUM

OF MEDICAL SCIENCE, containing Anatomy, Physiology, Surgery, Midwifery, Chemistry, Materia Medica, Therapeutics, and Practice of Medicine. By John Neill, M. D., and F. G. Smith, M. D. New and enlarged edition, one thick volume royal 12mo. of over 1000 pages, with 374 illustrations. ☞ See Neill, p. 24.

ABEL (F. A.), F. C. S. AND C. L. BLOXAM.

HANDBOOK OF CHEMISTRY, Theoretical, Practical, and Technical; with a Recommendatory Preface by Dr. Hofmann. In one large octavo volume, extra cloth, of 662 pages, with illustrations. $3 25.

ASHWELL (SAMUEL), M. D.,
Obstetric Physician and Lecturer to Guy's Hospital, London.

A PRACTICAL TREATISE ON THE DISEASES PECULIAR TO WOMEN. Illustrated by Cases derived from Hospital and Private Practice. Third American, from the Third and revised London edition. In one octavo volume, extra cloth, of 528 pages. $3 00.

The most useful practical work on the subject in the English language.—*Boston Med. and Surg. Journal.*

The most able, and certainly the most standard and practical, work on female diseases that we have yet seen.—*Medico-Chirurgical Review.*

ARNOTT (NEILL), M. D.

ELEMENTS OF PHYSICS; or Natural Philosophy, General and Medical. Written for universal use, in plain or non-technical language. A new edition, by Isaac Hays, M. D. Complete in one octavo volume, leather, of 484 pages, with about two hundred illustrations. $2 50.

BUDD (GEORGE), M. D., F. R. S.,
Professor of Medicine in King's College, London.

ON DISEASES OF THE LIVER. Third American, from the third and enlarged London edition. In one very handsome octavo volume, extra cloth, with four beautifully colored plates, and numerous wood-cuts. pp. 500. $3 00. (*Now Ready.*)

Has fairly established for itself a place among the classical medical literature of England.—*British and Foreign Medico-Chir. Review*, July, 1857.

Dr. Budd's Treatise on Diseases of the Liver is now a standard work in Medical literature, and during the intervals which have elapsed between the successive editions, the author has incorporated into the text the most striking novelties which have characterized the recent progress of hepatic physiology and pathology; so that although the size of the book is not perceptibly changed, the history of liver diseases is made more complete, and is kept upon a level with the progress of modern science. It is the best work on Diseases of the Liver in any language.—*London Med. Times and Gazette*, June 27, 1857.

This work, now the standard book of reference on the diseases of which it treats, has been carefully revised, and many new illustrations of the views of the learned author added in the present edition.—*Dublin Quarterly Journal*, Aug. 1857.

BY THE SAME AUTHOR.

ON THE ORGANIC DISEASES AND FUNCTIONAL DISORDERS OF THE STOMACH. In one neat octavo volume, extra cloth. $1 50.

From the high position occupied by Dr. Budd as a teacher, a writer, and a practitioner, it is almost needless to state that the present book may be consulted with great advantage. It is written in an easy style, the subjects are well arranged, and the practical precepts, both of diagnosis and treatment, denote the character of a thoughtful and experienced physician.—*London Med. Times and Gazette.*

BARCLAY (A. W.) M. D.,

Assistant Physician to St. George's Hospital, &c.

A MANUAL OF MEDICAL DIAGNOSIS; being an Analysis of the Signs and Symptoms of Disease. In one neat octavo volume, extra cloth, of 424 pages. (*Now Ready.*) $2 00.

Of works exclusively devoted to this important branch, our profession has at command, comparatively, but few, and, therefore, in the publication of the present work, Messrs. Blanchard & Lea have conferred a great favor upon us. Dr. Barclay, from having occupied, for a long period, the position of Medical Registrar at St. George's Hospital, possessed advantages for correct observation and reliable conclusions, as to the significance of symptoms, which have fallen to the lot of but few, either in his own or any other country. He has carefully systematized the results of his observation of over twelve thousand patients, and by his diligence and judicious classification, the profession has been presented with the most convenient and reliable work on the subject of Diagnosis that it has been our good fortune ever to examine; we can, therefore, say of Dr. Barclay's work, that, from his systematic manner of arrangement, his work is one of the best works "for reference" in the daily emergencies of the practitioner, with which we are acquainted; but, at the same time, we would recommend our readers, especially the younger ones, to read thoroughly and study diligently the *whole* work, and the "emergencies" will not occur so often.—*Southern Med. and Surg. Journ.*, March, 1858.

To give this information, to supply this admitted deficiency, is the object of Dr. Barclay's Manual. The task of composing such a work is neither an easy nor a light one; but Dr. Barclay has performed it in a manner which meets our most unqualified approbation. He is no mere theorist; he knows his work thoroughly, and in attempting to perform it, has not exceeded his powers. We have thus given a specimen of Barclay's generalizing spirit in one direction; but the same pervades his whole work, and will, we are sure, induce teachers to recommend it strongly to their pupils. It is impossible for us here to follow the book into its particulars; and, indeed, we think it enough to indicate, as we have done, the importance of the teaching which it offers to the rising generation of medicine, to insure for it a hearty reception at the hands of the profession. It is the work of a physician and a gentleman.—*British Med. Journal*, Dec. 5, 1857.

We hope the volume will have an extensive circulation, not among students of medicine only, but practitioners also. They will never regret a faithful study of its pages.—*Cincinnati Lancet*, Mar. '58.

This Manual of Medical Diagnosis is one of the most scientific, useful, and instructive works of its kind that we have ever read, and Dr. Barclay has done good service to medical science in collecting, arranging, and analyzing the signs and symptoms of so many diseases. It must have cost him great labor, and the profession should show their appreciation of it by their desire to procure and apply its valuable hints and suggestions to the thousand obscure cases which perplex and baffle the unaided efforts of any one man, be he ever so wise, and his opportunities ever so good. Another most valuable feature in the work is that it has been furnished with a copious index, which increases its utility very much as a volume of reference.—*N. J. Med. and Surg. Reporter*, March, 1858.

BARLOW (GEORGE H.), M. D.

Physician to Guy's Hospital, London, &c.

A MANUAL OF THE PRACTICE OF MEDICINE. With Additions by D. F. Condie, M. D., author of "A Practical Treatise on Diseases of Children," &c. In one handsome octavo volume, leather, of over 600 pages. (*A new work, just issued*, 1856.) $2 75.

We recommend Dr. Barlow's Manual in the warmest manner as a most valuable vade-mecum. We have had frequent occasion to consult it, and have found it clear, concise, practical, and sound. It is eminently a practical work, containing all that is essential, and avoiding useless theoretical discussion. The work supplies what has been for some time wanting, a manual of practice based upon modern discoveries in pathology and rational views of treatment of disease. It is especially intended for the use of students and junior practitioners, but it will be found hardly less useful to the experienced physician. The American editor has added to the work three chapters—on Cholera Infantum, Yellow Fever, and Cerebro-spinal Meningitis. These additions, the two first of which are indispensable to a work on practice destined for the profession in this country, are executed with great judgment and fidelity, by Dr. Condie, who has also succeeded happily in imitating the conciseness and clearness of style which are such agreeable characteristics of the original book.—*Boston Med. and Surg. Journal.*

BARTLETT (ELISHA), M. D.

THE HISTORY, DIAGNOSIS, AND TREATMENT OF THE FEVERS OF THE UNITED STATES. A new and revised edition. By Alonzo Clark, M. D., Prof. of Pathology and Practical Medicine in the N. Y. College of Physicians and Surgeons, &c. In one octavo volume, of six hundred pages, extra cloth. (*Now Ready.*) Price $3 00.

It is the best work on fevers which has emanated from the American press, and the present editor has carefully availed himself of all information existing upon the subject in the Old and New World, so that the doctrines advanced are brought down to the latest date in the progress of this department of Medical Science.—*London Med. Times and Gazette*, May 2, 1857.

This excellent monograph on febrile disease, has stood deservedly high since its first publication. It will be seen that it has now reached its fourth edition under the supervision of Prof. A. Clark, a gentleman who, from the nature of his studies and pursuits, is well calculated to appreciate and discuss the many intricate and difficult questions in pathology. His annotations add much to the interest of the work, and have brought it well up to the condition of the science as it exists at the present day in regard to this class of diseases.—*Southern Med. and Surg. Journal*, Mar. 1857.

It is a work of great practical value and interest, containing much that is new relative to the several diseases of which it treats, and, with the additions of the editor, is fully up to the times. The distinctive features of the different forms of fever are plainly and forcibly portrayed, and the lines of demarcation carefully and accurately drawn, and to the American practitioner is a more valuable and safe guide than any work on fever extant.—*Ohio Med. and Surg. Journal*, May, 1857.

CURLING (T. B.), F. R. S.,

Surgeon to the London Hospital, President of the Hunterian Society, &c.

A PRACTICAL TREATISE ON DISEASES OF THE TESTIS, SPERMATIC CORD, AND SCROTUM. Second American, from the second and enlarged English edition. In one handsome octavo volume, extra cloth, with numerous illustrations. pp. 420. (*Just Issued*, 1856.) $2 00.

CARPENTER (WILLIAM B.), M. D., F. R. S.,

Examiner in Physiology and Comparative Anatomy in the University of London.

(*Just Issued*, 1856.)

THE MICROSCOPE AND ITS REVELATIONS. With an Appendix containing the Applications of the Microscope to Clinical Medicine, &c. By F. G. Smith, M. D. Illustrated by four hundred and thirty-four beautiful engravings on wood. In one large and very handsome octavo volume, of 724 pages, extra cloth, $4 00; leather, $4 50.

Dr. Carpenter's position as a microscopist and physiologist, and his great experience as a teacher eminently qualify him to produce what has long been wanted—a good text-book on the practical use of the microscope. In the present volume his object has been, as stated in his Preface, "to combine, within a moderate compass, that information with regard to the use of his 'tools,' which is most essential to the working microscopist, with such an account of the objects best fitted for his study, as might qualify him to comprehend what he observes, and might thus prepare him to benefit science, whilst expanding and refreshing his own mind" That he has succeeded in accomplishing this, no one acquainted with his previous labors can doubt.

The great importance of the microscope as a means of diagnosis, and the number of microscopists who are also physicians, have induced the American publishers, with the author's approval, to add an Appendix, carefully prepared by Professor Smith, on the applications of the instrument to clinical medicine, together with an account of American Microscopes, their modifications and accessories. This portion of the work is illustrated with nearly one hundred wood-cuts, and, it is hoped, will adapt the volume more particularly to the use of the American student.

Every care has been taken in the mechanical execution of the work, which is confidently presented as in no respect inferior to the choicest productions of the London press.

The mode in which the author has executed his intentions may be gathered from the following condensed synopsis of the

CONTENTS.

Introduction—History of the Microscope. Chap. I. Optical Principles of the Microscope. Chap. II. Construction of the Microscope. Chap. III. Accessory Apparatus. Chap. IV. Management of the Microscope Chap. V. Preparation, Mounting, and Collection of Objects. Chap. VI. Microscopic Forms of Vegetable Life—Protophytes. Chap. VII. Higher Cryptogamia. Chap. VIII. Phanerogamic Plants. Chap. IX. Microscopic Forms of Animal Life—Protozoa—Animalcules. Chap. X. Foraminifera, Polycystina, and Sponges. Chap. XI. Zoophytes. Chap. XII. Echinodermata. Chap. XIII. Polyzoa and Compound Tunicata. Chap. XIV. Molluscous Animals Generally. Chap. XV. Annulosa. Chap. XVI. Crustacea. Chap. XVII. Insects and Arachnida. Chap. XVIII. Vertebrated Animals. Chap. XIX. Applications of the Microscope to Geology. Chap. XX. Inorganic or Mineral Kingdom—Polarization. Appendix. Microscope as a means of Diagnosis—Injections—Microscopes of American Manufacture.

Those who are acquainted with Dr. Carpenter's previous writings on Animal and Vegetable Physiology, will fully understand how vast a store of knowledge he is able to bring to bear upon so comprehensive a subject as the revelations of the microscope; and even those who have no previous acquaintance with the construction or uses of this instrument, will find abundance of information conveyed in clear and simple language.—*Med. Times and Gazette.*

Although originally not intended as a strictly medical work, the additions by Prof. Smith give it a positive claim upon the profession, for which we doubt not he will receive their sincere thanks. Indeed, we know not where the student of medicine will find such a complete and satisfactory collection of microscopic facts bearing upon physiology and practical medicine as is contained in Prof. Smith's appendix; and this of itself, it seems to us, is fully worth the cost of the volume.—*Louisville Medical Review*, Nov. 1856.

BY THE SAME AUTHOR.

ELEMENTS (OR MANUAL) OF PHYSIOLOGY, INCLUDING PHYSIOLOGICAL ANATOMY. Second American, from a new and revised London edition. With one hundred and ninety illustrations. In one very handsome octavo volume, leather. pp. 566. $3 00.

In publishing the first edition of this work, its title was altered from that of the London volume, by the substitution of the word "Elements" for that of "Manual," and with the author's sanction the title of "Elements" is still retained as being more expressive of the scope of the treatise.

To say that it is the best manual of Physiology now before the public, would not do sufficient justice to the author.—*Buffalo Medical Journal.*

In his former works it would seem that he had exhausted the subject of Physiology. In the present, he gives the essence, as it were, of the whole.—*N. Y. Journal of Medicine.*

Those who have occasion for an elementary treatise on Physiology, cannot do better than to possess themselves of the manual of Dr. Carpenter.—*Medical Examiner.*

The best and most complete exposé of modern Physiology, in one volume, extant in the English language.—*St. Louis Medical Journal.*

BY THE SAME AUTHOR. (*Preparing.*)

PRINCIPLES OF GENERAL PHYSIOLOGY, INCLUDING ORGANIC CHEMISTRY AND HISTOLOGY. With a General Sketch of the Vegetable and Animal Kingdom. In one large and very handsome octavo volume, with several hundred illustrations.

The subject of general physiology having been omitted in the last editions of the author's "Comparative Physiology" and "Human Physiology," he has undertaken to prepare a volume which shall present it more thoroughly and fully than has yet been attempted, and which may be regarded as an introduction to his other works.

BY THE SAME AUTHOR.

A PRIZE ESSAY ON THE USE OF ALCOHOLIC LIQUORS IN HEALTH AND DISEASE. New edition, with a Preface by D. F. Condie, M. D., and explanations of scientific words. In one neat 12mo. volume, extra cloth. pp. 178. 50 cents.

CHURCHILL (FLEETWOOD), M. D., M. R. I. A.

ON THE THEORY AND PRACTICE OF MIDWIFERY. Edited, with

Notes and Additions, by D. FRANCIS CONDIE, M. D., author of a "Practical Treatise on the Diseases of Children," &c. With 139 illustrations. In one very handsome octavo volume, leather. pp. 510. $3 00.

To bestow praise on a book that has received such marked approbation would be superfluous. We need only say, therefore, that if the first edition was thought worthy of a favorable reception by the medical public, we can confidently affirm that this will be found much more so. The lecturer, the practitioner, and the student, may all have recourse to its pages, and derive from their perusal much interest and instruction in everything relating to theoretical and practical midwifery.—*Dublin Quarterly Journal of Medical Science.*

A work of very great merit, and such as we can confidently recommend to the study of every obstetric practitioner.—*London Medical Gazette.*

This is certainly the most perfect system extant. It is the best adapted for the purposes of a textbook, and that which he whose necessities confine him to one book, should select in preference to all others.—*Southern Medical and Surgical Journal.*

The most popular work on midwifery ever issued from the American press.—*Charleston Med. Journal.*

Were we reduced to the necessity of having but *one* work on midwifery, and *permitted to choose*, we would unhesitatingly take Churchill.—*Western Med. and Surg. Journal.*

It is impossible to conceive a more useful and elegant manual than Dr. Churchill's Practice of Midwifery.—*Provincial Medical Journal.*

Certainly, in our opinion, the very best work on the subject which exists.—*N. Y. Annalist.*

No work holds a higher position, or is more deserving of being placed in the hands of the tyro, the advanced student, or the practitioner.—*Medical Examiner.*

Previous editions, under the editorial supervision of Prof R. M. Huston, have been received with marked favor, and they deserved it; but this, reprinted from a very late Dublin edition, carefully revised and brought up by the author to the present time, does present an unusually accurate and able exposition of every important particular embraced in the department of midwifery. * * The clearness, directness, and precision of its teachings, together with the great amount of statistical research which its text exhibits, have served to place it already in the foremost rank of works in this department of remedial science.—*N. O. Med. and Surg. Journal.*

In our opinion, it forms one of the best if not the very best text-book and epitome of obstetric science which we at present possess in the English language.—*Monthly Journal of Medical Science.*

The clearness and precision of style in which it is written, and the great amount of statistical research which it contains, have served to place it in the first rank of works in this department of medical science. —*N. Y. Journal of Medicine.*

Few treatises will be found better adapted as a text-book for the student, or as a manual for the frequent consultation of the young practitioner.—*American Medical Journal.*

BY THE SAME AUTHOR. (*Just Issued.*)

ON THE DISEASES OF INFANTS AND CHILDREN. Second American

Edition, revised and enlarged by the author. Edited, with Notes, by W. V. KEATING, M. D. In one large and handsome volume, extra cloth, of over 700 pages. $3 00, or in leather, $3 25.

In preparing this work a second time for the American profession, the author has spared no labor in giving it a very thorough revision, introducing several new chapters, and rewriting others, while every portion of the volume has been subjected to a severe scrutiny. The efforts of the American editor have been directed to supplying such information relative to matters peculiar to this country as might have escaped the attention of the author, and the whole may, therefore, be safely pronounced one of the most complete works on the subject accessible to the American Profession. By an alteration in the size of the page, these very extensive additions have been accommodated without unduly increasing the size of the work.

A few notices of the former edition are subjoined:—

We regard this volume as possessing more claims to completeness than any other of the kind with which we are acquainted. Most cordially and earnestly, therefore, do we commend it to our professional brethren, and we feel assured that the stamp of their approbation will in due time be impressed upon it. After an attentive perusal of its contents, we hesitate not to say, that it is one of the most comprehensive ever written upon the diseases of children, and that, for copiousness of reference, extent of research, and perspicuity of detail, it is scarcely to be equalled, and not to be excelled, in any language.—*Dublin Quarterly Journal.*

After this meagre, and we know, very imperfect notice of Dr. Churchill's work, we shall conclude by saying, that it is one that cannot fail from its copiousness, extensive research, and general accuracy, to exalt still higher the reputation of the author in this country. The American reader will be particularly pleased to find that Dr. Churchill has done full justice throughout his work to the various American authors on this subject. The names of Dewees, Eberle, Condie, and Stewart, occur on nearly every page, and these authors are constantly referred to by the author in terms of the highest praise, and with the most liberal courtesy.—*The Medical Examiner.*

The present volume will sustain the reputation acquired by the author from his previous works. The reader will find in it full and judicious directions for the management of infants at birth, and a compendious, but clear account of the diseases to which children are liable, and the most successful mode of treating them. We must not close this notice without calling attention to the author's style, which is perspicuous and polished to a degree, we regret to say, not generally characteristic of medical works. We recommend the work of Dr. Churchill most cordially, both to students and practitioners, as a valuable and reliable guide in the treatment of the diseases of children.—*Am. Journ. of the Med. Sciences.*

We know of no work on this department of Practical Medicine which presents so candid and unprejudiced a statement or posting up of our actual knowledge as this.—*N. Y. Journal of Medicine.*

Its claims to merit both as a scientific and practical work, are of the highest order. Whilst we would not elevate it above every other treatise on the same subject, we certainly believe that very few are equal to it, and none superior.—*Southern Med. and Surgical Journal.*

BY THE SAME AUTHOR.

ESSAYS ON THE PUERPERAL FEVER, AND OTHER DISEASES PECULIAR TO WOMEN.

Selected from the writings of British Authors previous to the close of the Eighteenth Century. In one neat octavo volume, extra cloth, of about 450 pages. $2 50.

DRUITT (ROBERT), M. R. C. S., &c.

THE PRINCIPLES AND PRACTICE OF MODERN SURGERY. Edited by F. W. SARGENT, M. D., author of "Minor Surgery," &c. Illustrated with one hundred and ninety-three wood-engravings. In one very handsomely printed octavo volume, leather, of 576 large pages. $3 00.

Dr. Druitt's researches into the literature of his subject have been not only extensive, but well directed; the most discordant authors are fairly and impartially quoted, and, while due credit is given to each, their respective merits are weighed with an unprejudiced hand. The grain of wheat is preserved, and the chaff is unmercifully stripped off. The arrangement is simple and philosophical, and the style, though clear and interesting, is so precise, that the book contains more information condensed into a few words than any other surgical work with which we are acquainted.—*London Medical Times and Gazette.*

No work, in our opinion, equals it in presenting so much valuable surgical matter in so small a compass.—*St. Louis Med. and Surgical Journal.*

Druitt's Surgery is too well known to the American medical profession to require its announcement anywhere. Probably no work of the kind has ever been more cordially received and extensively circulated than this. The fact that it comprehends in a comparatively small compass, all the essential elements of theoretical and practical Surgery—that it is found to contain reliable and authentic information on the nature and treatment of nearly all surgical affections—is a sufficient reason for the liberal patronage it has obtained. The editor, Dr. F. W. Sargent, has contributed much to enhance the value of the work, by such American improvements as are calculated more perfectly to adapt it to our own views and practice in this country. It abounds everywhere with spirited and life-like illustrations, which to the young surgeon, especially, are of no minor consideration. Every medical man frequently needs just such a work as this, for immediate reference in moments of sudden emergency, when he has not time to consult more elaborate treatises.—*The Ohio Medical and Surgical Journal.*

The author has evidently ransacked every standard treatise of ancient and modern times, and all that is really practically useful at the bedside will be found in a form at once clear, distinct, and interesting.—*Edinburgh Monthly Medical Journal.*

Druitt's work, condensed, systematic, lucid, and practical as it is, beyond most works on Surgery accessible to the American student, has had much currency in this country, and under its present auspices promises to rise to yet higher favor.—*The Western Journal of Medicine and Surgery.*

The most accurate and ample resumé of the present state of Surgery that we are acquainted with.—*Dublin Medical Journal.*

A better book on the principles and practice of Surgery as now understood in England and America, has not been given to the profession.—*Boston Medical and Surgical Journal.*

An unsurpassable compendium, not only of Surgical, but of Medical Practice.—*London Medical Gazette.*

This work merits our warmest commendations, and we strongly recommend it to young surgeons as an admirable digest of the principles and practice of modern Surgery.—*Medical Gazette.*

It may be said with truth that the work of Mr. Druitt affords a complete, though brief and condensed view, of the entire field of modern surgery. We know of no work on the same subject having the appearance of a manual, which includes so many topics of interest to the surgeon; and the terse manner in which each has been treated evinces a most enviable quality of mind on the part of the author, who seems to have an innate power of searching out and grasping the leading facts and features of the most elaborate productions of the pen. It is a useful handbook for the practitioner, and we should deem a teacher of surgery unpardonable who did not recommend it to his pupils. In our own opinion, it is admirably adapted to the wants of the student.—*Provincial Medical and Surgical Journal.*

DUNGLISON, FORBES, TWEEDIE, AND CONOLLY.

THE CYCLOPÆDIA OF PRACTICAL MEDICINE: comprising Treatises on the Nature and Treatment of Diseases, Materia Medica, and Therapeutics, Diseases of Women and Children, Medical Jurisprudence, &c. &c. In four large super-royal octavo volumes, of 3254 double-columned pages, strongly and handsomely bound, with raised bands. $12 00.

*** This work contains no less than four hundred and eighteen distinct treatises, contributed by sixty-eight distinguished physicians, rendering it a complete library of reference for the country practitioner.

The most complete work on Practical Medicine extant; or, at least, in our language.—*Buffalo Medical and Surgical Journal.*

For reference, it is above all price to every practitioner.—*Western Lancet.*

One of the most valuable medical publications of the day—as a work of reference it is invaluable.—*Western Journal of Medicine and Surgery.*

It has been to us, both as learner and teacher, a work for ready and frequent reference, one in which modern English medicine is exhibited in the most advantageous light.—*Medical Examiner.*

We rejoice that this work is to be placed within the reach of the profession in this country, it being unquestionably one of very great value to the practitioner. This estimate of it has not been formed from a hasty examination, but after an intimate acquaintance derived from frequent consultation of it during the past nine or ten years. The editors are practitioners of established reputation, and the list of contributors embraces many of the most eminent professors and teachers of London, Edinburgh, Dublin, and Glasgow. It is, indeed, the great merit of this work that the principal articles have been furnished by practitioners who have not only devoted especial attention to the diseases about which they have written, but have also enjoyed opportunities for an extensive practical acquaintance with them, and whose reputation carries the assurance of their competency justly to appreciate the opinions of others, while it stamps their own doctrines with high and just authority.—*American Medical Journ.*

DEWEES'S COMPREHENSIVE SYSTEM OF MIDWIFERY. Illustrated by occasional cases and many engravings. Twelfth edition, with the author's last improvements and corrections. In one octavo volume, extra cloth, of 600 pages. $3 20.

DEWEES'S TREATISE ON THE PHYSICAL AND MEDICAL TREATMENT OF CHILDREN. Tenth edition. In one volume, octavo, extra cloth, 548 pages. $2 80.

DEWEES'S TREATISE ON THE DISEASES OF FEMALES. Tenth edition. In one volume, octavo, extra cloth, 532 pages, with plates. $3 00.

DANA ON ZOOPHYTES AND CORALS. In one volume, imperial quarto, extra cloth, with wood-cuts. $15 00. Also, AN ATLAS, in one volume, imperial folio, with sixty-one magnificent colored plates. Bound in half morocco. $30 00.

DE LA BECHE'S GEOLOGICAL OBSERVER. In one very large and handsome octavo volume, extra cloth, of 700 pages, with 300 wood-cuts. $4 00.

FRICK ON RENAL AFFECTIONS; their Diagnosis and Pathology. With illustrations. One volume, royal 12mo., extra cloth. 75 cents.

DUNGLISON (ROBLEY), M. D.,

Professor of Institutes of Medicine in the Jefferson Medical College, Philadelphia.

HUMAN PHYSIOLOGY. Eighth edition. Thoroughly revised and extensively modified and enlarged, with five hundred and thirty-two illustrations. In two large and handsomely printed octavo volumes, leather, of about 1500 pages. (*Just Issued*, 1856.) $7 00.

In revising this work for its eighth appearance, the author has spared no labor to render it worthy a continuance of the very great favor which has been extended to it by the profession. The whole contents have been rearranged, and to a great extent remodelled; the investigations which of late years have been so numerous and so important, have been carefully examined and incorporated, and the work in every respect has been brought up to a level with the present state of the subject. The object of the author has been to render it a concise but comprehensive treatise, containing the whole body of physiological science, to which the student and man of science can at all times refer with the certainty of finding whatever they are in search of, fully presented in all its aspects; and on no former edition has the author bestowed more labor to secure this result.

We believe that it can truly be said, no more complete repertory of facts upon the subject treated, can anywhere be found. The author has, moreover, that enviable tact at description and that facility and ease of expression which render him peculiarly acceptable to the casual, or the studious reader. This faculty, so requisite in setting forth many graver and less attractive subjects, lends additional charms to one always fascinating.—*Boston Med. and Surg. Journal*, Sept. 1856.

The most complete and satisfactory system of Physiology in the English language.—*Amer. Med. Journal.*

The best work of the kind in the English language.—*Silliman's Journal.*

The present edition the author has made a perfect mirror of the science as it is at the present hour. As a work upon physiology proper, the science of the functions performed by the body, the student will find it all he wishes.—*Nashville Journ. of Med.* Sept. 1856.

That he has succeeded, most admirably succeeded in his purpose, is apparent from the appearance of an eighth edition. It is now the great encyclopædia on the subject, and worthy of a place in every physician's library.—*Western Lancet*, Sept. 1856.

BY THE SAME AUTHOR. (*Now Ready.*)

GENERAL THERAPEUTICS AND MATERIA MEDICA; adapted for a Medical Text-book. With Indexes of Remedies and of Diseases and their Remedies. SIXTH EDITION, revised and improved. With one hundred and ninety-three illustrations. In two large and handsomely printed octavo vols., leather, of about 1100 pages. $6 00.

From the Author's Preface.

"Another edition of this work being called for, the author has subjected it to a thorough and careful revision. It has been gratifying to him that it has been found so extensively useful by those for whom it was especially intended, as to require that a *sixth* edition should be issued in so short a time after the publication of a fifth. Grateful for the favorable reception of the work by the profession, he has bestowed on the preparation of the present edition all those cares which were demanded by the former editions, and has spared no pains to render it a faithful epitome of General Therapeutics and Materia Medica. The copious Indexes of Remedies and of Diseases and their Remedies cannot fail, the author conceives, to add materially to the value of the work."

This work is too widely and too favorably known to require more than the assurance that the author has revised it with his customary industry, introducing whatever has been found necessary to bring it on a level with the most advanced condition of the subject. The number of illustrations has been somewhat enlarged, and the mechanical execution of the volumes will be found to have undergone a decided improvement.

BY THE SAME AUTHOR. (*A new Edition.*)

NEW REMEDIES, WITH FORMULÆ FOR THEIR PREPARATION AND ADMINISTRATION. Seventh edition, with extensive Additions. In one very large octavo volume, leather, of 770 pages. (*Just Issued.*) $3 75.

Another edition of the "New Remedies" having been called for, the author has endeavored to add everything of moment that has appeared since the publication of the last edition.

The chief remedial means which have obtained a place, for the first time, in this volume, either owing to their having been recently introduced into pharmacology, or to their having received novel applications—and which, consequently, belong to the category of "New Remedies"—are the following:—

Apiol, Caffein, Carbazotic acid, Cauterization and catheterism of the larynx and trachea, Cedron, Cerium, Chloride of bromine, Chloride of iron, Chloride of sodium, Cinchonicine, Cod-liver olein, Congelation, Eau de Pagliari, Galvanic cautery, Hydriodic ether, Hyposulphite of soda and silver, Inunction, Iodide of sodium, Nickel, Permanganate of potassa, Phosphate of lime, Pumpkin, Quinidia, Rennet, Saccharine carbonate of iron and manganese, Santonin, Tellurium, and Traumaticine.

The articles treated of in the former editions will be found to have undergone considerable expansion in this, in order that the author might be enabled to introduce, as far as practicable, the results of the subsequent experience of others, as well as of his own observation and reflection; and to make the work still more deserving of the extended circulation with which the preceding editions have been favored by the profession. By an enlargement of the page, the numerous additions have been incorporated without greatly increasing the bulk of the volume.—*Preface.*

One of the most useful of the author's works.—*Southern Medical and Surgical Journal.*

This elaborate and useful volume should be found in every medical library, for as a book of reference, for physicians, it is unsurpassed by any other work in existence, and the double index for diseases and for remedies, will be found greatly to enhance its value.—*New York Med. Gazette.*

The great learning of the author, and his remarkable industry in pushing his researches into every source whence information is derivable, have enabled him to throw together an extensive mass of facts and statements, accompanied by full reference to authorities; which last feature renders the work practically valuable to investigators who desire to examine the original papers.—*The American Journal of Pharmacy.*

FLINT (AUSTIN), M. D.,

Professor of the Theory and Practice of Medicine in the University of Louisville, &c.

(An Important New Work.)

PHYSICAL EXPLORATION AND DIAGNOSIS OF DISEASES AFFECTING THE RESPIRATORY ORGANS. In one large and handsome octavo volume, extra cloth, 636 pages. $3 00.

We can only state our general impression of the high value of this work, and cordially recommend it to all. We regard it, in point both of arrangement and of the marked ability of its treatment of the subjects, as destined to take the first rank in works of this class. So far as our information extends, it has at present no equal. To the practitioner, as well as the student, it will be invaluable in clearing up the diagnosis of doubtful cases, and in shedding light upon difficult phenomena.—*Buffalo Med. Journal.*

This is the most elaborate work devoted exclusively to the physical exploration of diseases of the lungs, with which we are acquainted in the English language. From the high standing of the author as a clinical teacher, and his known devotion, during many years, to the study of thoracic diseases, much was to be expected from the announcement of his determination to embody in the form of a treatise, the results of his study and experience. These expectations we are confident will not be disappointed. For our own part, we have been favorably impressed by a perusal of the book, and heartily recommend it to all who are desirous of acquiring a thorough acquaintance with the means of exploring the conditions of the respiratory organs by means of auscultation and percussion.—*Boston Med. and Surg. Journal.*

A work of original observation of the highest merit. We recommend the treatise to every one who wishes to become a correct auscultator. Based to a very large extent upon cases numerically examined, it carries the evidence of careful study and discrimination upon every page. It does credit to the author, and, through him, to the profession in this country. It is, what we cannot call every book upon auscultation, a readable book.—*Am. Jour. Med. Sciences.*

NOW COMPLETE.

GRAHAM (THOMAS), F. R. S.,

THE ELEMENTS OF INORGANIC CHEMISTRY, including the Applications of the Science in the Arts. New and much enlarged edition, by Henry Watts and Robert Bridges, M. D. Complete in one large and handsome octavo volume, of over 800 very large pages, with two hundred and thirty-two wood-cuts, extra cloth. $4 00.

*** Part II., completing the work from p. 431 to end, with Index, Title Matter, &c., may be had separate, cloth backs and paper sides. Price $2 50.

The long delay which has intervened since the appearance of the first portion of this work, has rendered necessary an Appendix, embodying the numerous and important investigations and discoveries of the last few years in the subjects contained in Part I. This occupies a large portion of Part II., and will be found to present a complete abstract of the most recent researches in the general principles of the science, as well as all details necessary to bring the whole work thoroughly up to the present time in all departments of Inorganic Chemistry.

The great reputation which this work has enjoyed since its first appearance, and its recognized position in the front rank of scientific treatises, render eulogy unnecessary to secure for it immediate attention on the part of those desiring to procure a complete exposition of chemical facts and principles, either as an introduction to the subject for the student, or as a work for daily reference by the practical chemist.

Gentlemen desirous of completing their copies of the work are requested to apply for Part II. without delay. It will be sent by mail, prepaid, on receipt of the amount, $2 50.

It is a very acceptable addition to the library of standard books of every chemical student. Mr. Watts, well known as the translator of the Cavendish Society edition of Gmelin's Chemistry, has made in the supplement an able résumé of the progress of the science since the publication of the first volume. It is plain from the number and importance of the topics there discussed, that great progress has been made in the interval, both in chemical physics and in general inorganic chemistry. No reader of English works on this science can afford to be without this edition of Prof. Graham's Elements.—*Silliman's Journal*, March, 1858.

GRIFFITH (ROBERT E.), M. D., &c.

A UNIVERSAL FORMULARY, containing the methods of Preparing and Administering Officinal and other Medicines. The whole adapted to Physicians and Pharmaceutists. Second Edition, thoroughly revised, with numerous additions, by Robert P. Thomas, M. D., Professor of Materia Medica in the Philadelphia College of Pharmacy. In one large and handsome octavo volume, extra cloth, of 650 pages, double columns. (*Just Issued.*) $3 00; or bound in sheep, $3 25.

It was a work requiring much perseverance, and when published was looked upon as by far the best work of its kind that had issued from the American press. Prof Thomas has certainly "improved," as well as added to this Formulary, and has rendered it additionally deserving of the confidence of pharmaceutists and physicians.—*Am. Journal of Pharmacy.*

We are happy to announce a new and improved edition of this, one of the most valuable and useful works that have emanated from an American pen. It would do credit to any country, and will be found of daily usefulness to practitioners of medicine; it is better adapted to their purposes than the dispensatories.—*Southern Med. and Surg. Journal.*

It is one of the most useful books a country practitioner can possibly have in his possession.—*Medical Chronicle.*

This is a work of six hundred and fifty-one pages, embracing all on the subject of preparing and administering medicines that can be desired by the physician and pharmaceutist.—*Western Lancet.*

The amount of useful, every-day matter, for a practicing physician, is really immense.—*Boston Med. and Surg. Journal.*

We predict a great sale for this work, and we especially recommend it to all medical teachers.—*Richmond Stethoscope.*

This edition of Dr. Griffith's work has been greatly improved by the revision and ample additions of Dr. Thomas, and is now, we believe, one of the most complete works of its kind in any language. The additions amount to about seventy pages, and no effort has been spared to include in them all the recent improvements which have been published in medical journals, and systematic treatises. A work of this kind appears to us indispensable to the physician, and there is none we can more cordially recommend.—*N. Y. Journal of Medicine.*

BY THE SAME AUTHOR.

MEDICAL BOTANY; or, a Description of all the more important Plants used in Medicine, and of their Properties, Uses, and Modes of Administration. In one large octavo volume, extra cloth, of 704 pages, handsomely printed, with nearly 350 illustrations on wood. $3 00.

HOBLYN (RICHARD D.), M. D.

A DICTIONARY OF THE TERMS USED IN MEDICINE AND THE COLLATERAL SCIENCES. By Richard D. Hoblyn, A. M., &c. A new American edition. Revised, with numerous Additions, by Isaac Hays, M. D., editor of the "American Journal of the Medical Sciences." In one large royal 12mo. volume, leather, of over 500 double columned pages. (*Just Issued*, 1856.) $1 50.

If the frequency with which we have referred to this volume since its reception from the publisher, two or three weeks ago, be any criterion for the future, the binding will soon have to be renewed, even with careful handling. We find that Dr. Hays has done the profession great service by his careful and industrious labors. The Dictionary has thus become eminently suited to our medical brethren in this country. The additions by Dr. Hays are in brackets, and we believe there is not a single page but bears these insignia; in every instance which we have thus far noticed, the additions are really needed and exceedingly valuable. We heartily commend the work to all who wish to be *au courant* in medical terminology.—*Boston Med. and Surg. Journal.*

To both practitioner and student, we recommend this dictionary as being convenient in size, accurate in definition, and sufficiently full and complete for ordinary consultation.—*Charleston Med. Journ. and Review.*

Admirably calculated to meet the wants of the practitioner or student, who has neither the means nor desire to procure a larger work.—*American Lancet.*

Hoblyn has always been a favorite dictionary, and in its present enlarged and improved form will give greater satisfaction than ever. The American editor, Dr. Hays, has made many very valuable additions. —*N. J. Med. Reporter.*

To supply the want of the medical reader arising from this cause, we know of no dictionary better arranged and adapted than the one bearing the above title. It is not encumbered with the obsolete terms of a bygone age, but it contains all that are now in use; embracing every department of medical science down to the very latest date. The volume is of a convenient size to be used by the medical student, and yet large enough to make a respectable appearance in the library of a physician.—*Western Lancet.*

Hoblyn's Dictionary has long been a favorite with us. It is the best book of definitions we have, and ought always to be upon the student's table.—*Southern Med. and Surg. Journal.*

HOLLAND (SIR HENRY), BART., M. D., F. R. S.,

Physician in Ordinary to the Queen of England, &c.

MEDICAL NOTES AND REFLECTIONS. From the third London edition. In one handsome octavo volume, extra cloth. (*Now Ready.*) $3 00.

As the work of a thoughtful and observant physician, embodying the results of forty years' active professional experience, on topics of the highest interest, this volume is commended to the American practitioner as well worthy his attention. Few will rise from its perusal without feeling their convictions strengthened, and armed with new weapons for the daily struggle with disease.

HABERSHON (S. O.), M. D.,

Assistant Physician to and Lecturer on Materia Medica and Therapeutics at Guy's Hospital, &c.

PATHOLOGICAL AND PRACTICAL OBSERVATIONS ON DISEASES OF THE ALIMENTARY CANAL, ŒSOPHAGUS, STOMACH, CÆCUM, AND INTESTINES. With illustrations on wood. In one handsome octavo volume. (*Republishing in the Medical News and Library for* 1858.)

HORNER (WILLIAM E.), M. D.,

Professor of Anatomy in the University of Pennsylvania.

SPECIAL ANATOMY AND HISTOLOGY. Eighth edition. Extensively revised and modified. In two large octavo volumes, extra cloth, of more than one thousand pages, handsomely printed, with over three hundred illustrations. $6 00.

HAMILTON (FRANK H.), M. D.,

Professor of Surgery, in Buffalo Medical College, &c.

A TREATISE ON FRACTURES AND DISLOCATIONS. In one handsome octavo volume, with numerous illustrations. (*Preparing.*)

JONES (T. WHARTON), F. R. S.,

Professor of Ophthalmic Medicine and Surgery in University College, London, &c.

THE PRINCIPLES AND PRACTICE OF OPHTHALMIC MEDICINE AND SURGERY. With one hundred and ten illustrations. Second American from the second and revised London edition, with additions by Edward Hartshorne, M. D., Surgeon to Wills' Hospital, &c. In one large, handsome royal 12mo. volume, extra cloth, of 500 pages. $1 50.

We are confident that the reader will find, on perusal, that the execution of the work amply fulfils the promise of the preface, and sustains, in every point, the already high reputation of the author as an ophthalmic surgeon as well as a physiologist and pathologist. The book is evidently the result of much labor and research, and has been written with the greatest care and attention; it possesses that best quality which a general work, like a system or manual can show, viz: the quality of having all the materials whencesoever derived, so thoroughly wrought up, and digested in the author's mind, as to come forth with the freshness and impressiveness of an original production. We entertain little doubt that this book will become what its author hoped it might become, a manual for daily reference and consultation by the student and the general practitioner. The work is marked by that correctness, clearness, and precision of style which distinguish all the productions of the learned author.—*British and For. Med. Review.*

MEIGS (CHARLES D.), M. D.,

Professor of Obstetrics, &c. in the Jefferson Medical College, Philadelphia.

OBSTETRICS: THE SCIENCE AND THE ART. Third edition, revised and improved. With one hundred and twenty-nine illustrations. In one beautifully printed octavo volume, leather, of seven hundred and fifty-two large pages. $3 75.

The rapid demand for another edition of this work is a sufficient expression of the favorable verdict of the profession. In thus preparing it a third time for the press, the author has endeavored to render it in every respect worthy of the favor which it has received. To accomplish this he has thoroughly revised it in every part. Some portions have been rewritten, others added, new illustrations have been in many instances substituted for such as were not deemed satisfactory, while, by an alteration in the typographical arrangement, the size of the work has not been increased, and the price remains unaltered. In its present improved form, it is, therefore, hoped that the work will continue to meet the wants of the American profession as a sound, practical, and extended SYSTEM OF MIDWIFERY.

Though the work has received only five pages of enlargement, its chapters throughout wear the impress of careful revision. Expunging and rewriting, remodelling its sentences, with occasional new material, all evince a lively desire that it shall deserve to be regarded as improved in *manner* as well as *matter*. In the *matter*, every stroke of the pen has increased the value of the book, both in expungings and additions.—*Western Lancet*, Jan. 1857.

The best American work on Midwifery that is accessible to the student and practitioner—*N. W. Med. and Surg. Journal*, Jan. 1857.

This is a standard work by a great American Obstetrician. It is the third and last edition, and, in the language of the preface, the author has "brought the subject up to the latest dates of real improvement in our art and Science."—*Nashville Journ. of Med. and Surg.*, May, 1857.

BY THE SAME AUTHOR. (*Lately Issued.*)

WOMAN: HER DISEASES AND THEIR REMEDIES. A Series of Lectures to his Class. Third and Improved edition. In one large and beautifully printed octavo volume, leather. pp. 672. $3 60.

The gratifying appreciation of his labors, as evinced by the exhaustion of two large impressions of this work within a few years, has not been lost upon the author, who has endeavored in every way to render it worthy of the favor with which it has been received. The opportunity thus afforded for a second revision has been improved, and the work is now presented as in every way superior to its predecessors, additions and alterations having been made whenever the advance of science has rendered them desirable. The typographical execution of the work will also be found to have undergone a similar improvement, and the work is now confidently presented as in every way worthy the position it has acquired as the standard American text-book on the Diseases of Females.

It contains a vast amount of practical knowledge, by one who has accurately observed and retained the experience of many years, and who tells the result in a free, familiar, and pleasant manner.—*Dublin Quarterly Journal.*

There is an off-hand fervor, a glow, and a warmheartedness infecting the effort of Dr. Meigs, which is entirely captivating, and which absolutely hurries the reader through from beginning to end. Besides, the book teems with solid instruction, and it shows the very highest evidence of ability, viz., the clearness with which the information is presented. We know of no better test of one's understanding a subject than the evidence of the power of lucidly explaining it. The most elementary, as well as the obscurest subjects, under the pencil of Prof. Meigs, are isolated and made to stand out in such bold relief, as to produce distinct impressions upon the mind and memory of the reader.—*The Charleston Med. Journal.*

Professor Meigs has enlarged and amended this great work, for such it unquestionably is, having passed the ordeal of criticism at home and abroad, but been improved thereby; for in this new edition the author has introduced real improvements, and increased the value and utility of the book immeasurably. It presents so many novel, bright, and sparkling thoughts; such an exuberance of new ideas on almost every page, that we confess ourselves to have become enamored with the book and its author; and cannot withhold our congratulations from our Philadelphia confreres, that such a teacher is in their service.—*N. Y. Med. Gazette.*

BY THE SAME AUTHOR. (*Lately Published.*)

ON THE NATURE, SIGNS, AND TREATMENT OF CHILDBED FEVER. In a Series of Letters addressed to the Students of his Class. In one handsome octavo volume, extra cloth, of 365 pages. $2 50.

The instructive and interesting author of this work, whose previous labors in the department of medicine which he so sedulously cultivates, have placed his countrymen under deep and abiding obligations, again challenges their admiration in the fresh and vigorous, attractive and racy pages before us. It is a delectable book. * * * This treatise upon child-bed fevers will have an extensive sale, being destined, as it deserves, to find a place in the library of every practitioner who scorns to lag in the rear.—*Nashville Journal of Medicine and Surgery.*

This book will add more to his fame than either of those which bear his name. Indeed we doubt whether any material improvement will be made on the teachings of this volume for a century to come, since it is so eminently practical, and based on profound knowledge of the *science* and consummate skill in the *art* of healing, and ratified by an ample and extensive experience, such as few men have the industry or good fortune to acquire.—*N. Y. Med. Gazette.*

BY THE SAME AUTHOR; WITH COLORED PLATES.

A TREATISE ON ACUTE AND CHRONIC DISEASES OF THE NECK OF THE UTERUS. With numerous plates, drawn and colored from nature in the highest style of art. In one handsome octavo volume, extra cloth. $4 50.

MAYNE'S DISPENSATORY AND THERAPEUTICAL REMEMBRANCER. Comprising the entire lists of Materia Medica, with every Practical Formula contained in the three British Pharmacopœias. Edited, with the addition of the Formulæ of the U. S. Pharmacopœia, by R. E. GRIFFITH, M. D. 1 12mo. vol. ex. cl., 300 pp. 75 c.

MALGAIGNE'S OPERATIVE SURGERY, based on Normal and Pathological Anatomy. Translated from the French by FREDERICK BRITTAN, A. B., M. D. With numerous illustrations on wood. In one handsome octavo volume, extra cloth, of nearly six hundred pages. $2 25.

MACLISE (JOSEPH), S

SURGICAL ANATOMY. Forming one vol

With sixty-eight large and splendid Plates, drawn in th taining one hundred and ninety Figures, many of them and explanatory letter-press. Strongly and handsomel cheapest and best executed Surgical works as yet issue

*** The size of this work prevents its transmission thr who desire to have copies forwarded by mail, can rece wrappers. Price $9 00.

One of the greatest artistic triumphs of the age in Surgical Anatomy.—*British American Medical Journal.*

Too much cannot be said in its praise; indeed, we have not language to do it justice.—*Ohio Medical and Surgical Journal.*

The most admirable surgical atlas we have seen. To the practitioner deprived of demonstrative dissections upon the human subject, it is an invaluable companion.—*N. J. Medical Reporter.*

The most accurately engraved and beautifully colored plates we have ever seen in an American book—one of the best and cheapest surgical works ever published.—*Buffalo Medical Journal.*

It is very rare that so elegantly printed, so well illustrated, and so useful a work, is offered at so moderate a price.—*Charleston Medical Journal.*

Its plates can boast a superiority which places them almost beyond the reach of competition.—*Medical Examiner.*

Every practitioner, we think, should have a work of this kind within reach.—*Southern Medical and Surgical Journal.*

No such lithographic illustrations of surgical regions have hitherto, we think, been given.—*Boston Medical and Surgical Journal.*

As a surgical anatomist, Mr. Maclise has probably no superior.—*British and Foreign Medico-Chirurgical Review.*

Of great value to the student engaged in dissecting, and to the surgeon at a distance from the means

of keep *Times.*

The *Transy*

A wo racy an *Journa*

To a profess *Dublin*

No p fail to

Coun mense

We profess work, valled, colorin subject *Surgic*

This tomy know dent, i tion. arise, of mini keeps t fresh in *cine an*

☞ The very low price at which this work is furn require an extended sale to compensate the publisher

MULLER'S PRINCIPLES OF PHYSICS A

with Additions, by R. Eglesfeld Griffith, M. D. In extra cloth, with 550 wood-cuts, and two colored plate

MOHR (FRANCIS), PH. D., AND RE

PRACTICAL PHARMACY. Comprising t

Manipulations of the Pharmaceutical Shop and Labor by Prof. William Procter, of the Philadelphia Co printed octavo volume, extra cloth, of 570 pages, with

MACKENZIE (W.)

Surgeon Oculist in Scotland in ordinary

A PRACTICAL TREATISE ON DISEAS

EYE. To which is prefixed an Anatomical Introduct the Human Eyeball, by Thomas Wharton Jones, F. larged London Edition. With Notes and Additions b Wills Hospital, &c. &c. In one very large and handsome plates and numerous wood-cuts. $5 25.

The treatise of Dr. Mackenzie indisputably holds the first place, and forms, in respect of learning and research, an Encyclopædia unequalled in extent by any other work of the kind, either English or foreign. —*Dixon on Diseases of the Eye.*

Few modern books on any department of medicine or surgery have met with such extended circulation, or have procured for their authors a like amount of European celebrity. The immense research which it displayed, the thorough acquaintance with the subject, practically as well as theoretically, and the able manner in which the author's stores of learning and experience were rendered available for general use, at once procured for the first edition, as well on the continent as in this country, that high position as a standard work which each successive edition has more firmly established, in spite of the attractions of several rivals of no mean ability. We con-

sider it profess make h work i the eye

The doubt h tions. for the the mos Eye" h no figu *Foreig*

This treatise industr he has —Dub

MILLER (JAMES), F. R. S. E.,

Professor of Surgery in the University of Edinburgh, &c.

PRINCIPLES OF SURGERY. Fourth American, from the third and revised Edinburgh edition. In one large and very beautiful volume, leather, of 700 pages, with two hundred and forty exquisite illustrations on wood. (*Just Issued*, 1856.) $3 75.

The extended reputation enjoyed by this work will be fully maintained by the present edition. Thoroughly revised by the author, it will be found a clear and compendious exposition of surgical science in its most advanced condition.

In connection with the recently issued third edition of the author's "Practice of Surgery," it forms a very complete system of Surgery in all its branches.

The work of Mr. Miller is too well and too favorably known among us, as one of our best text-books, to render any further notice of it necessary than the announcement of a new edition, the *fourth* in our country, a proof of its extensive circulation among us. As a concise and reliable exposition of the science of modern surgery, it stands deservedly high—we know not its superior.—*Boston Med. and Surg. Journal.*

It presents the most satisfactory exposition of the modern doctrines of the principles of surgery to be found in any volume in any language.—*N. Y. Journal of Medicine.*

The work takes rank with Watson's Practice of Physic; it certainly does not fall behind that great work in soundness of principle or depth of reasoning and research. No physician who values his reputation, or seeks the interests of his clients, can acquit himself before his God and the world without making himself familiar with the sound and philosophical views developed in the foregoing book.—*New Orleans Med. and Surg. Journal.*

Without doubt the ablest exposition of the principles of that branch of the healing art in any language. This opinion, deliberately formed after a careful study of the first edition, we have had no cause to change on examining the second. This edition has undergone thorough revision by the author; many expressions have been modified, and a mass of new matter introduced. The book is got up in the finest style, and is an evidence of the progress of typography in our country.—*Charleston Medical Journal and Review.*

BY THE SAME AUTHOR. (*Now Ready.*)

THE PRACTICE OF SURGERY. Fourth American from the last Edinburgh edition. Revised by the American editor. Illustrated by three hundred and sixty-four engravings on wood. In one large octavo volume, leather, of nearly 700 pages. $3 75.

No encomium of ours could add to the popularity of Miller's Surgery. Its reputation in this country is unsurpassed by that of any other work, and, when taken in connection with the author's *Principles of Surgery*, constitutes a whole, without reference to which no conscientious surgeon would be willing to practice his art. The additions, by Dr. Sargent, have materially enhanced the value of the work.—*Southern Medical and Surgical Journal.*

It is seldom that two volumes have ever made so profound an impression in so short a time as the "Principles" and the "Practice" of Surgery by Mr. Miller—or so richly merited the reputation they have acquired. The author is an eminently sensible, practical, and well-informed man, who knows exactly what he is talking about and exactly how to talk it.—*Kentucky Medical Recorder.*

By the almost unanimous voice of the profession, his works, both on the principles and practice of surgery have been assigned the highest rank. If we were limited to but one work on surgery, that one should be Miller's, as we regard it as superior to all others.—*St. Louis Med. and Surg. Journal.*

The author, distinguished alike as a practitioner and writer, has in this and his "Principles," presented to the profession one of the most complete and reliable systems of Surgery extant. His style of writing is original, impressive, and engaging, energetic, concise, and lucid. Few have the faculty of condensing so much in small space, and at the same time so persistently holding the attention; indeed, he appears to make the very process of condensation a means of eliminating attractions. Whether as a text-book for students or a book of reference for practitioners, it cannot be too strongly recommended.—*Southern Journal of Med. and Phys. Sciences.*

MONTGOMERY (W. F.), M. D., M. R. I. A., &c.,

Professor of Midwifery in the King and Queen's College of Physicians in Ireland, &c.

AN EXPOSITION OF THE SIGNS AND SYMPTOMS OF PREGNANCY. With some other Papers on Subjects connected with Midwifery. From the second and enlarged English edition. With two exquisite colored plates, and numerous wood-cuts. In one very handsome octavo volume, extra cloth, of nearly 600 pages. (*Just Issued*, 1857.) $3 75.

The present edition of this classical volume is fairly entitled to be regarded as a new work, every sentence having been carefully rewritten, and the whole increased to more than double the original size. The title of the work scarcely does justice to the extent and importance of the topics brought under consideration, embracing, with the exception of the operative procedures of midwifery, almost everything connected with obstetrics, either directly or incidentally; and there are few physicians who will not find in its pages much that will prove of great interest and value in their daily practice. The special Essays on the Period of Human Gestation, the Signs of Delivery, and the Spontaneous Amputation and other Lesions of the Fœtus in Utero present topics of the highest interest fully treated and beautifully illustrated.

In every point of mechanical execution the work will be found one of the handsomest yet issued from the American press.

A book unusually rich in practical suggestions.—*Am. Journal Med. Sciences*, Jan. 1857.

These several subjects so interesting in themselves, and so important, every one of them, to the most delicate and precious of social relations, controlling often the honor and domestic peace of a family, the legitimacy of offspring, or the life of its parent, are all treated with an elegance of diction, fulness of illustrations, acuteness and justice of reasoning, unparalleled in obstetrics, and unsurpassed in medicine. The reader's interest can never flag, so fresh, and vigorous, and classical is our author's style; and one forgets, in the renewed charm of every page, that it, and every line, and every word has been weighed and reweighed through years of preparation; that this is of all others the book of Obstetric Law, on each of its several topics; on all points connected with pregnancy, to be everywhere received as a manual of special jurisprudence, at once announcing fact, affording argument, establishing precedent, and governing alike the juryman, advocate, and judge. It is not merely in its legal relations that we find this work so interesting. Hardly a page but that has its hints or facts important to the general practitioner; and not a chapter without especial matter for the anatomist, physiologist, or pathologist.—*N. A. Med.-Chir. Review*, March, 1857.

NEILL (JOHN),

Surgeon to the Pennsylvania E

FRANCIS GURNEY S

Professor of Institutes of Medicine in the F

AN ANALYTICAL COMPENDIUM OF

OF MEDICAL SCIENCE; for the Use and Examin and improved. In one very large and handsomely thousand pages, with 374 wood-cuts. Strongly boun

The very flattering reception which has been accorde upon it by the profession, as evinced by the constant an hausted two large editions, have stimulated the authors more worthy of the success which has attended it. It and such errors as had on former occasions escaped obs additions were necessary to maintain it on a level with t The extended series of illustrations has been still furth a slight enlargement of the page, these various addition the bulk of the volume.

The work is, therefore, again presented as eminently w been received. As a book for daily reference by the st text-books, as a manual for preceptors desiring to stimu examination, or as a source from which the practitioners a knowledge of the changes and improvement in profes established.

The best work of the kind with which we are acquainted.—*Med. Examiner.*

Having made free use of this volume in our examinations of pupils, we can speak from experience in recommending it as an admirable compend for students, and as especially useful to preceptors who examine their pupils. It will save the teacher much labor by enabling him readily to recall all of the points upon which his pupils should be examined. A work of this sort should be in the hands of every one who takes pupils into his office with a view of examining them; and this is unquestionably the best of its class.—*Transylvania Med. Journal.*

In the rapid course of lectures, where work for

the s' exam it is in mo of al newe prove conci to wh as we ates who perh now *scope*

NEILL (JOHN),

Professor of Surgery in the Pennsylva

OUTLINES OF THE VEINS AND LYM

plates. 1 vol., cloth. $1 25.

OUTLINES OF THE NERVES. With har

NELIGAN (J. MOORE), M.

(A splendid work. J

ATLAS OF CUTANEOUS DISEASES. I

cloth, with splendid colored plates, presenting nearl disease. $1 50.

This beautiful volume is intended as a complete and of Diseases of the Skin. While it can be consulted in co especial reference to the author's "Treatise on Disease profession some years since. The publishers feel justi cuted plates have ever been presented to the professio

A compend which will very much aid the practitioner in this difficult branch of diagnosis. Taken with the beautiful plates of the Atlas, which are remarkable for their accuracy and beauty of coloring, it constitutes a very valuable addition to the library of a practical man.—*Buffalo Med. Journal*, Sept. 1856.

Nothing is often more difficult than the diagnosis of disease of the skin; and hitherto, the only works containing illustrations have been at rather inconvenient prices—prices, indeed, that prevented general use. The work before us will supply a want long felt, and minister to a more perfect acquaintance with the nature and treatment of a very frequent and troublesome form of disease.—*Ohio Med. and Surg. Journal*, July, 1856.

Neligan's Atlas of Cutaneous Diseases supplies a

long class 16 pl fore of ta ; get have with of in give, of ca ease of pr tion. has t coul the *Men*

BY THE SAME AU

A PRACTICAL TREATISE ON DISE

American edition. In one neat royal 12mo. volume,

☞ The two volumes will be sent by mail

OWEN ON THE DIFFERENT FORMS OF THE SKELETON, AND OF THE TEETH.

(Now Complete.)

PEREIRA (JONATHAN), M. D., F. R. S., AND L. S.

THE ELEMENTS OF MATERIA MEDICA AND THERAPEUTICS.

Third American edition, enlarged and improved by the author; including Notices of most of the Medicinal Substances in use in the civilized world, and forming an Encyclopædia of Materia Medica. Edited, with Additions, by JOSEPH CARSON, M. D., Professor of Materia Medica and Pharmacy in the University of Pennsylvania. In two very large octavo volumes of 2100 pages, on small type, with about 500 illustrations on stone and wood, strongly bound in leather, with raised bands. $9 00.

Gentlemen who have the first volume are recommended to complete their copies without delay. The first volume will no longer be sold separate. Price of Vol. II. $5 00.

The third edition of his "Elements of Materia Medica, although completed under the supervision of others, is by far the most elaborate treatise in the English language, and will, while medical literature is cherished, continue a monument alike honorable to his genius, as to his learning and industry.—*American Journal of Pharmacy.*

Our own opinion of its merits is that of its editors, and also that of the whole profession, both of this and foreign countries—namely, "that in copiousness of details, in extent, variety, and accuracy of information, and in lucid explanation of difficult and recondite subjects, it surpasses all other works on Materia Medica hitherto published." We cannot close this notice without alluding to the special additions of the American editor, which pertain to the prominent vegetable productions of this country, and to the directions of the United States Pharmacopœia, in connection with all the articles contained in the volume which are referred to by it. The illustrations have been increased, and this edition by Dr. Carson cannot well be regarded in any other light than that of a treasure which should be found in the library of every physician.—*New York Journal of Medical and Collateral Science.*

The work, in its present shape, forms the most comprehensive and complete treatise on materia medica extant in the English language. The accounts of the physiological and therapeutic effects of remedies are given with great clearness and accuracy, and in a manner calculated to interest as well as instruct the reader.—*Edinburgh Medical and Surgical Journal.*

PEASLEE (E. R.), M. D.,

Professor of Physiology and General Pathology in the New York Medical College.

HUMAN HISTOLOGY, in its relations to Anatomy, Physiology, and Pathology;

for the use of Medical Students. With four hundred and thirty-four illustrations. In one handsome octavo volume, of over 600 pages. (*Now Ready.*) $3 75.

The rapid advances made of late years in our knowledge of the structure and functions of the elements which constitute the human body, have rendered the subject of Histology of the highest importance to all who regard medicine as a science. At the same time, the vast body of facts covered by Physiology has caused our text-books on that subject to be necessarily restricted in their treatment of the portions devoted to Histology. A want has, therefore, arisen of a work devoted especially to the minute anatomy of the body, giving a complete and detailed account of the structure of the various tissues, as well as the solids and fluids, in all the different organs—their functions in health, and their changes in disease. In undertaking this task, the author has endeavored to present his extensive subject in the manner most likely to interest and benefit the physician, confident that in these details will be found the basis of true medical science. The very large number of illustrations introduced throughout, serves amply to elucidate the text, while the typography of the volume will in every respect be found of the handsomest description.

It embraces a library upon the topics discussed within itself, and is just what the teacher and learner need. Another advantage, by no means to be overlooked, everything of real value in the wide range which it embraces, is with great skill compressed into an octavo volume of but little more than six hundred pages. We have not only the whole subject of Histology, interesting in itself, ably and fully discussed, but what is of infinitely greater interest to the student, because of greater practical value, are its relations to Anatomy, Physiology, and Pathology, which are here fully and satisfactorily set forth. These great supporting branches of practical medicine are thus linked together, and while establishing and illustrating each other, are interwoven into a harmonious whole. We commend the work to students and physicians generally.—*Nashville Journ. of Med. and Surgery*, Dec. 1857.

It far surpasses our expectation. We never conceived the possibility of compressing so much valuable information into so compact a form. We will not consume space with commendations. We receive this contribution to physiological science, "Not with vain thanks, but with acceptance bounteous." We have already paid it the practical compliment of making abundant use of it in the preparation of our lectures, and also of recommending its further perusal most cordially to our alumni; a recommendation which we now extend to our readers.—*Memphis Med. Recorder*, Jan. 1858.

PIRRIE (WILLIAM), F. R. S. E.,

Professor of Surgery in the University of Aberdeen.

THE PRINCIPLES AND PRACTICE OF SURGERY. Edited by JOHN

NEILL, M. D., Professor of Surgery in the Penna. Medical College, Surgeon to the Pennsylvania Hospital, &c. In one very handsome octavo volume, leather, of 780 pages, with 316 illustrations. $3 75.

We know of no other surgical work of a reasonable size, wherein there is so much theory and practice, or where subjects are more soundly or clearly taught.—*The Stethoscope.*

There is scarcely a disease of the bones or soft parts, fracture, or dislocation, that is not illustrated by accurate wood-engravings. Then, again, every instrument employed by the surgeon is thus represented. These engravings are not only correct, but really beautiful, showing the astonishing degree of perfection to which the art of wood-engraving has arrived. Prof. Pirrie, in the work before us, has elaborately discussed the principles of surgery, and a safe and effectual practice predicated upon them. Perhaps no work upon this subject heretofore issued is so full upon the science of the art of surgery.—*Nashville Journal of Medicine and Surgery.*

One of the best treatises on surgery in the English language.—*Canada Med. Journal.*

Our impression is, that, as a manual for students, Pirrie's is the best work extant.—*Western Med. and Surg. Journal.*

PARKER (LANGSTON),

Surgeon to the Queen's Hospital, Birmingham.

THE MODERN TREATMENT OF SYPHILITIC DISEASES, BOTH PRIMARY AND SECONDARY;

comprising the Treatment of Constitutional and Confirmed Syphilis, by a safe and successful method. With numerous Cases, Formulæ, and Clinical Observations. *From the Third and entirely rewritten London edition.* In one neat octavo volume, *extra cloth, of 316 pages.* $1 75.

PARRISH (EDWARD),

Lecturer on Practical Pharmacy and Materia Medica in the Pennsylvania Academy of Medicine, &c.

AN INTRODUCTION TO PRACTICAL PHARMACY. Designed as a Text-Book for the Student, and as a Guide for the Physician and Pharmaceutist. With many Formulæ and Prescriptions. In one handsome octavo volume, extra cloth, of 550 pages, with 243 Illustrations. $2 75.

A careful examination of this work enables us to speak of it in the highest terms, as being the best treatise on practical pharmacy with which we are acquainted, and an invaluable *vade-mecum*, not only to the apothecary and to those practitioners who are accustomed to prepare their own medicines, but to every medical man and medical student. Throughout the work are interspersed valuable tables, useful formulæ, and practical hints, and the whole is illustrated by a large number of excellent wood-engravings.—*Boston Med. and Surg. Journal.*

This is altogether one of the most useful books we have seen. It is just what we have long felt to be needed by apothecaries, students, and practitioners of medicine, most of whom in this country have to put up their own prescriptions. It bears, upon every page, the impress of practical knowledge, conveyed in a plain common sense manner, and adapted to the comprehension of all who may read it. No detail has been omitted, however trivial it may seem, although really important to the dispenser of medicine.—*Southern Med. and Surg. Journal.*

To both the country practitioner and the city apothecary this work of Mr. Parrish is a godsend. A careful study of its contents will give the young graduate a familiarity with the value and mode of administering his prescriptions, which will be of as much use to his patient as to himself.—*Va. Med. Journal.*

Mr. Parrish has rendered a very acceptable service to the practitioner and student, by furnishing this book, which contains the leading facts and principles of the science of Pharmacy, conveniently arranged for study, and with special reference to those features of the subject which possess an especial practical interest to the physician. It furnishes the student, at the commencement of his studies, with that information which is of the greatest importance in initiating him into the domain of Chemistry and Materia Medica; it familiarizes him with the compounding of drugs, and supplies those minutiæ which but few practitioners can impart. The junior practitioner will, also, find this volume replete with instruction.—*Charleston Med. Journal and Review*, Mar. 1856.

There is no useful information in the details of the apothecary's or country physician's office conducted according to science that is omitted. The young physician will find it an encyclopedia of indispensable medical knowledge, from the purchase of a spatula to the compounding of the most learned prescriptions. The work is by the ablest pharmaceutist in the United States, and must meet with an immense sale.—*Nashville Journal of Medicine*, April, 1856.

We are glad to receive this excellent work. It will supply a want long felt by the profession, and especially by the student of Pharmacy. A large majority of physicians are obliged to compound their own medicines, and to them a work of this kind is indispensable.—*N. O. Medical and Surgical Journal.*

We cannot say but that this volume is one of the most welcome and appropriate which has for a long time been issued from the press. It is a work which we doubt not will at once secure an extensive circulation, as it is designed not only for the druggist and pharmaceutist, but also for the great body of practitioners throughout the country, who not only have to prescribe medicines, but in the majority of instances have to rely upon their own resources—whatever these may be—not only to compound, but also to manufacture the remedies they are called upon to administer. The author has not mistaken the idea in writing this volume, as it is alike useful and invaluable to those engaged in the active pursuits of the profession, and to those preparing to enter upon the field of professional labors.—*American Lancet*, March 24, 1856.

RICORD (P.), M. D.,

A TREATISE ON THE VENEREAL DISEASE. By JOHN HUNTER, F.R.S. With copious Additions, by PH. RICORD, M. D. Edited, with Notes, by FREEMAN J. BUMSTEAD, M. D. In one handsome octavo volume, extra cloth, of 520 pages, with plates. $3 25.

Every one will recognize the attractiveness and value which this work derives from thus presenting the opinions of these two masters side by side. But, it must be admitted, what has made the fortune of the book, is the fact that it contains the "most complete embodiment of the veritable doctrines of the Hôpital du Midi," which has ever been made public. The doctrinal ideas of M. Ricord, ideas which, if not universally adopted, are incontestably dominant, have heretofore only been interpreted by more or less skilful secretaries, sometimes accredited and sometimes not.

In the notes to Hunter, the master substitutes himself for his interpreters, and gives his original thoughts to the world in a lucid and perfectly intelligible manner. In conclusion we can say that this is incontestably the best treatise on syphilis with which we are acquainted, and, as we do not often employ the phrase, we may be excused for expressing the hope that it may find a place in the library of every physician.—*Virginia Med. and Surg. Journal.*

BY THE SAME AUTHOR.

ILLUSTRATIONS OF SYPHILITIC DISEASE. Translated by THOMAS F. BETTON, M. D. With fifty large quarto colored plates. In one large quarto volume, extra cloth. $15 00.

LETTERS ON SYPHILIS, addressed to the Chief Editor of the Union Médicale. Translated by W. P. LATTIMORE, M. D. In one neat octavo volume, of 270 pages, extra cloth. $2 00.

RIGBY (EDWARD), M. D.,

Senior Physician to the General Lying-in Hospital, &c.

A SYSTEM OF MIDWIFERY. With Notes and Additional Illustrations. Second American Edition. One volume octavo, extra cloth, 422 pages. $2 50.

BY THE SAME AUTHOR. (*Now Ready*, 1857.)

ON THE CONSTITUTIONAL TREATMENT OF FEMALE DISEASES. In one neat royal 12mo. volume, extra cloth, of about 250 pages. $1 00.

The aim of the author has been throughout to present sound practical views of the important subjects under consideration; and without entering into theoretical disputations and disquisitions, to embody the results of his long and extended experience in such a condensed form as would be easily accessible to the practitioner.

ROYLE'S MATERIA MEDICA AND THERAPEUTICS; including the Preparations of the Pharmacopœias of London, Edinburgh, Dublin, and of the United States. With many new medicines. Edited by JOSEPH CARSON, M. D. With ninety-eight Illustrations. In one large octavo volume, extra cloth, of about 700 pages. $3 00.

RAMSBOTHAM (FRANCIS H.), M. D.

THE PRINCIPLES AND PRACTICE OF OBSTETRIC MEDICINE AND SURGERY,

in reference to the Process of Parturition. A new and enlarged edition, thoroughly revised by the Author. With Additions by W. V. KEATING, M. D. In one large and handsome imperial octavo volume, of 650 pages, strongly bound in leather, with raised bands; with sixty-four beautiful Plates, and numerous Wood-cuts in the text, containing in all nearly two hundred large and beautiful figures. (*Lately Issued*, 1856.) $5 00.

In calling the attention of the profession to the new edition of this standard work, the publishers would remark that no efforts have been spared to secure for it a continuance and extension of the remarkable favor with which it has been received. The last London issue, which was considerably enlarged, has received a further revision from the author, especially for this country. Its passage through the press here has been supervised by Dr. Keating, who has made numerous additions with a view of presenting more fully whatever was necessary to adapt it thoroughly to American modes of practice. In its mechanical execution, a like superiority over former editions will be found.

From Prof. Hodge, of the University of Pa.

To the American public, it is most valuable, from its intrinsic undoubted excellence, and as being the best authorized exponent of British Midwifery. Its circulation will, I trust, be extensive throughout our country.

The publishers have shown their appreciation of the merits of this work and secured its success by the truly elegant style in which they have brought it out, excelling themselves in its production, especially in its plates. It is dedicated to Prof. Meigs, and has the emphatic endorsement of Prof. Hodge, as the best exponent of British Midwifery. We know of no text-book which deserves in all respects to be more highly recommended to students, and we could wish to see it in the hands of every practitioner, for they will find it invaluable for reference.—*Med. Gazette.*

But once in a long time some brilliant genius rears his head above the horizon of science, and illuminates and purifies every department that he investigates; and his works become types, by which innumerable imitators model their feeble productions. Such a genius we find in the younger Ramsbotham, and such a type we find in the work now before us. The binding, paper, type, the engravings and wood-cuts are all so excellent as to make this book one of the finest specimens of the art of printing that have given such a world-wide reputation to its enterprising and liberal publishers. We welcome Ramsbotham's Principles and Practice of Obstetric Medicine and Surgery to our library, and confidently recommend it to our readers, with the assurance that it will not disappoint their most sanguine expectations.—*Western Lancet.*

It is unnecessary to say anything in regard to the utility of this work. It is already appreciated in our country for the value of the matter, the clearness of its style, and the fulness of its illustrations. To the physician's library it is indispensable, while to the student as a text-book, from which to extract the material for laying the foundation of an education on obstetrical science, it has no superior.—*Ohio Med. and Surg. Journal.*

We will only add that the student will learn from it all he need to know, and the practitioner will find it, as a book of reference, surpassed by none other.—*Stethoscope.*

The character and merits of Dr. Ramsbotham's work are so well known and thoroughly established, that comment is unnecessary and praise superfluous. The illustrations, which are numerous and accurate, are executed in the highest style of art. We cannot too highly recommend the work to our readers.—*St. Louis Med. and Surg. Journal.*

ROKITANSKY (CARL), M. D.,

Curator of the Imperial Pathological Museum, and Professor at the University of Vienna, &c.

A MANUAL OF PATHOLOGICAL ANATOMY.

Four volumes, octavo, bound in two, extra cloth, of about 1200 pages. Translated by W. E. SWAINE, EDWARD SIEVEKING, C. H. MOORE, and G. E. DAY. (*Just Issued.*) $5 50

To render this large and important work more easy of reference, and at the same time less cumbrous and costly, the four volumes have been arranged in two, retaining, however, the separate paging, &c.

The publishers feel much pleasure in presenting to the profession of the United States the great work of Prof. Rokitansky, which is universally referred to as the standard of authority by the pathologists of all nations. Under the auspices of the Sydenham Society of London, the combined labor of four translators has at length overcome the almost insuperable difficulties which have so long prevented the appearance of the work in an English dress. To a work so widely known, eulogy is unnecessary, and the publishers would merely state that it is said to contain the results of not less than THIRTY THOUSAND *post-mortem* examinations made by the author, diligently compared, generalized, and wrought into one complete and harmonious system.

The profession is too well acquainted with the reputation of Rokitansky's work to need our assurance that this is one of the most profound, thorough, and valuable books ever issued from the medical press. It is *sui generis*, and has no standard of comparison. It is only necessary to announce that it is issued in a form as cheap as is compatible with its size and preservation, and its sale follows as a matter of course. No library can be called complete without it.—*Buffalo Med. Journal.*

An attempt to give our readers any adequate idea of the vast amount of instruction accumulated in these volumes, would be feeble and hopeless. The effort of the distinguished author to concentrate in a small space his great fund of knowledge, has so charged his text with valuable truths, that any attempt of a reviewer to epitomize is at once paralyzed, and must end in a failure.—*Western Lancet.*

As this is the highest source of knowledge upon the important subject of which it treats, no real student can afford to be without it. The American publishers have entitled themselves to the thanks of the profession of their country, for this timeous and beautiful edition.—*Nashville Journal of Medicine.*

As a book of reference, therefore, this work must prove of inestimable value, and we cannot too highly recommend it to the profession.—*Charleston Med. Journal and Review*, Jan. 1856.

This book is a necessity to every practitioner.—*Am. Med. Monthly.*

SCHOEDLER (FRIEDRICH), PH. D.,

Professor of the Natural Sciences at Worms, &c.

THE BOOK OF NATURE;

an Elementary Introduction to the Sciences of Physics, Astronomy, Chemistry, Mineralogy, Geology, Botany, Zoology, and Physiology. First American edition, with a Glossary and other Additions and Improvements; from the second English edition. Translated from the sixth German edition, by HENRY MEDLOCK, F.C.S., &c. *In one volume, small octavo, extra cloth, pp. 692, with 679 illustrations.* $1 80.

SHARPEY (WILLIAM), M. D., JONES QUAIN, M. D., AND RICHARD QUAIN, F. R. S., &c.

HUMAN ANATOMY. Revised, with Notes and Additions, by JOSEPH LEIDY, M. D., Professor of Anatomy in the University of Pennsylvania. Complete in two large octavo volumes, leather, of about thirteen hundred pages. Beautifully illustrated with over five hundred engravings on wood. $6 00.

It is indeed a work calculated to make an era in anatomical study, by placing before the student every department of his science, with a view to the relative importance of each; and so skilfully have the different parts been interwoven, that no one who makes this work the basis of his studies, will hereafter have any excuse for neglecting or undervaluing any important particulars connected with the structure of the human frame; and whether the bias of his mind lead him in a more especial manner to surgery, physic, or physiology, he will find here a work at once so comprehensive and practical as to defend him from exclusiveness on the one hand, and pedantry on the other.—*Journal and Retrospect of the Medical Sciences.*

We have no hesitation in recommending this treatise on anatomy as the most complete on that subject in the English language; and the only one, perhaps, in any language, which brings the state of knowledge forward to the most recent discoveries.—*The Edinburgh Med. and Surg. Journal.*

SMITH (W. TYLER), M. D.,

Physician Accoucheur to St. Mary's Hospital, &c.

ON PARTURITION, AND THE PRINCIPLES AND PRACTICE OF OBSTETRICS. In one royal 12mo. volume, extra cloth, of 400 pages. $1 25.

BY THE SAME AUTHOR.

A PRACTICAL TREATISE ON THE PATHOLOGY AND TREATMENT OF LEUCORRHŒA. With numerous illustrations. In one very handsome octavo volume, extra cloth, of about 250 pages. $1 50.

We hail the appearance of this practical and invaluable work, therefore, as a real acquisition to our medical literature.—*Medical Gazette.*

TAYLOR (ALFRED S.), M. D., F. R. S.,

Lecturer on Medical Jurisprudence and Chemistry in Guy's Hospital.

MEDICAL JURISPRUDENCE. Fourth American, from the fifth improved and enlarged English Edition. With Notes and References to American Decisions, by EDWARD HARTSHORNE, M. D. In one large octavo volume, leather, of over seven hundred pages. (*Just Issued*, 1856.) $3 00.

This standard work has lately received a very thorough revision at the hands of the author, who has introduced whatever was necessary to render it complete and satisfactory in carrying out the objects in view. The editor has likewise used every exertion to make it equally thorough with regard to all matters relating to the practice of this country. In doing this, he has carefully examined all that has appeared on the subject since the publication of the last edition, and has incorporated all the new information thus presented. The work has thus been considerably increased in size, notwithstanding which, it has been kept at its former very moderate price, and in every respect it will be found worthy of a continuance of the remarkable favor which has carried it through so many editions on both sides of the Atlantic. A few notices of the former editions are appended.

We know of no work on Medical Jurisprudence which contains in the same space anything like the same amount of valuable matter.—*N. Y. Journal of Medicine.*

No work upon the subject can be put into the hands of students either of law or medicine which will engage them more closely or profitably; and none could be offered to the busy practitioner of either calling, for the purpose of casual or hasty reference, that would be more likely to afford the aid desired. We therefore recommend it as the best and safest manual for daily use.—*American Journal of Medical Sciences.*

This work of Dr. Taylor's is generally acknowledged to be one of the ablest extant on the subject of medical jurisprudence. It is certainly one of the most attractive books that we have met with; supplying so much both to interest and instruct, that we do not hesitate to affirm that after having once commenced its perusal, few could be prevailed upon to desist before completing it. In the last London edition, all the newly observed and accurately recorded facts have been inserted, including much that is recent of Chemical, Microscopical, and Pathological research, besides papers on numerous subjects never before published.—*Charleston Medical Journal and Review.*

It is not excess of praise to say that the volume before us is the very best treatise extant on Medical Jurisprudence. In saying this, we do not wish to be understood as detracting from the merits of the excellent works of Beck, Ryan, Traill, Guy, and others; but in interest and value we think it must be conceded that Taylor is superior to anything that has preceded it.—*N. W. Medical and Surg. Journal.*

BY THE SAME AUTHOR.

ON POISONS, IN RELATION TO MEDICAL JURISPRUDENCE AND MEDICINE. Edited, with Notes and Additions, by R. E. GRIFFITH, M. D. In one large octavo volume, leather, of 688 pages. $3 00

TANNER (T. H.), M. D.,

Physician to the Hospital for Women, &c.

A MANUAL OF CLINICAL MEDICINE AND PHYSICAL DIAGNOSIS. To which is added The Code of Ethics of the American Medical Association. Second American Edition. In one neat volume, small 12mo. Price in extra cloth, 87½ cents; flexible style, for the pocket, 80 cents.

The work is an honor to its writer, and must obtain a wide circulation by its intrinsic merit alone. Suited alike to the wants of students and practitioners, it has only to be seen, to win for itself a place upon the shelves of every medical library. Nor will it be "shelved" long at a time; if we mistake not, *it will be found, in the best sense of the* homely but expressive word, "handy." The style is admirably clear, while it is so sententious as not to burden the memory. The arrangement is, to our mind, unexceptionable. The work, in short, deserves the heartiest commendation.—*Boston Med. and Surg. Journal.*

Now Complete (April, 1857.)

TODD (ROBERT BENTLEY), M. D., F. R. S.,

Professor of Physiology in King's College, London; and

WILLIAM BOWMAN, F. R. S.,

Demonstrator of Anatomy in King's College, London.

THE PHYSIOLOGICAL ANATOMY AND PHYSIOLOGY OF MAN.

With about three hundred large and beautiful illustrations on wood. Complete in one large octavo volume, of 950 pages, leather. Price $4 50.

The very great delay which has occurred in the completion of this work has arisen from the desire of the authors to verify by their own examination the various questions and statements presented, thus rendering the work one of peculiar value and authority. By the wideness of its scope and the accuracy of its facts it thus occupies a position of its own, and becomes necessary to all physiological students.

☞ Gentlemen who have received portions of this work, as published in the "MEDICAL NEWS AND LIBRARY," can now complete their copies, if immediate application be made. It will be furnished as follows, free by mail, in paper covers, with cloth backs.

PARTS I., II., III. (pp. 25 to 552), $2 50.
PART IV. (pp. 553 to end, with Title, Preface, Contents, &c.), $2 00.
Or, PART IV., SECTION II. (pp. 725 to end, with Title, Preface, Contents, &c.), $1 25.

A magnificent contribution to British medicine, and the American physician who shall fail to peruse it, will have failed to read one of the most instructive books of the nineteenth century.—*N. O. Med and Surg. Journal*, Sept. 1857.

It is more concise than Carpenter's Principles, and more modern than the accessible edition of Müller's Elements; its details are brief, but sufficient; its descriptions vivid; its illustrations exact and copious; and its language terse and perspicuous.—*Charleston Med. Journal*, July, 1857.

We recommend this work not only for its many original investigations especially into the minute anatomy and physiology of man, but we admire the constant association of anatomy with physiology. The motive power is studied in its connections and adaptations to the machine it is destined to guide, and the student feels constantly impressed with the necessity for an accurate knowledge of the structure of the human body before he can make himself master of its functions.—*Va. Med. Journal*, June, 1857.

We know of no work on the subject of physiology so well adapted to the wants of the medical student. Its completion has been thus long delayed, that the authors might secure accuracy by personal observation.—*St. Louis Med. and Surg. Journal*, Sept. '57.

One of the very best books ever issued from any medical press. We think it indispensable to every reading medical man, and it may, with all propriety, and with the utmost advantage be made a text-book by any student who would thoroughly comprehend the groundwork of medicine.—*N. O. Med. News*, June, 1857.

Our notice, though it conveys but a very feeble and imperfect idea of the magnitude and importance of the work now under consideration, already transcends our limits; and, with the indulgence of our readers, and the hope that they will peruse the book for themselves, as we feel we can with confidence recommend it, we leave it in their hands for them to judge of its merits.—*The Northwestern Med. and Surg. Journal*, Oct. 1857.

It has been a far more pleasant task to us to point out its features of remarkable excellence, and to show in how many particulars the results which it embodies of skilful and zealous research do the highest credit to its able and accomplished authors. It would be a serious omission were we not to take special notice of the admirable and copious illustrations, the execution of which (by Mr. Vasey) is in the very finest style of wood-engraving.—*Brit. and For. Medico-Chir. Review*, Jan. 1858.

TODD (R. B.), M. D., F. R. S., &c.

CLINICAL LECTURES ON CERTAIN DISEASES OF THE URINARY ORGANS AND ON DROPSIES.

In one octavo volume. (*Now Ready*, 1857.) $1 50

The valuable practical nature of Dr. Todd's writings have deservedly rendered them favorites with the profession, and the present volume, embodying the medical aspects of a class of diseases not elsewhere to be found similarly treated, can hardly fail to supply a want long felt by the practitioner

WATSON (THOMAS), M. D., &c.

LECTURES ON THE PRINCIPLES AND PRACTICE OF PHYSIC.

Third American edition, revised, with Additions, by D. FRANCIS CONDIE, M. D., author of a "Treatise on the Diseases of Children," &c. In one octavo volume, of nearly eleven hundred large pages, strongly bound with raised bands. $3 25.

To say that it is the very best work on the subject now extant, is but to echo the sentiment of the medical press throughout the country.—*N. O. Medical Journal*.

Of the text-books recently republished Watson is very justly the principal favorite.—*Holmes's Rep. to Nat. Med. Assoc.*

By universal consent the work ranks among the very best text-books in our language.—*Illinois and Indiana Med. Journal*.

Regarded on all hands as one of the very best, if not the very best, systematic treatise on practical medicine extant.—*St. Louis Med. Journal*.

Confessedly one of the very best works on the principles and practice of physic in the English or any other language.—*Med. Examiner*.

As a text-book it has no equal; as a compendium of pathology and practice no superior.—*New York Annalist*.

We know of no work better calculated for being placed in the hands of the student, and for a text-book; on every important point the author seems to have posted up his knowledge to the day.—*Amer. Med. Journal*.

One of the most practically useful books that ever was presented to the student.—*N. Y. Med. Journal*.

WHAT TO OBSERVE

AT THE BEDSIDE AND AFTER DEATH, IN MEDICAL CASES.

Published under the authority of the London Society for Medical Observation. A new American, from the second and revised London edition. In one very handsome volume, royal 12mo., extra cloth. $1 00.

To the observer who prefers accuracy to blunders and precision to carelessness, this little book is invaluable.—*N. H. Journal of Medicine*.

One of the finest aids to a young practitioner we have ever seen.—*Peninsular Journal of Medicine*.

WILSON (ERASMUS), M. D., F. R. S.,
Lecturer on Anatomy, London.

A SYSTEM OF HUMAN ANATOMY, General and Special. Fourth American, from the last English edition. Edited by PAUL B. GODDARD, A. M., M. D. With two hundred and fifty illustrations. Beautifully printed, in one large octavo volume, leather, of nearly six hundred pages. $3 00.

In many, if not all the Colleges of the Union, it has become a standard text-book. This, of itself, is sufficiently expressive of its value. A work very desirable to the student; one, the possession of which will greatly facilitate his progress in the study of Practical Anatomy.—*New York Journal of Medicine.*

Its author ranks with the highest on Anatomy.—*Southern Medical and Surgical Journal.*

It offers to the student all the assistance that can be expected from such a work.—*Medical Examiner.*

The most complete and convenient manual for the student we possess.—*American Journal of Medical Science.*

In every respect, this work as an anatomical guide for the student and practitioner, merits our warmest and most decided praise.—*London Medical Gazette.*

BY THE SAME AUTHOR. (*Just Issued.*)

THE DISSECTOR'S MANUAL; or, Practical and Surgical Anatomy. Third American, from the last revised and enlarged English edition. Modified and rearranged, by WILLIAM HUNT, M. D., Demonstrator of Anatomy in the University of Pennsylvania. In one large and handsome royal 12mo. volume, leather, of 582 pages, with 154 illustrations. $2 00.

The modifications and additions which this work has received in passing recently through the author's hands, is sufficiently indicated by the fact that it is enlarged by more than one hundred pages, notwithstanding that it is printed in smaller type, and with a greatly enlarged page.

It remains only to add, that after a careful examination, we have no hesitation in recommending this work to the notice of those for whom it has been expressly written—the students—as a guide possessing very superior claims, well calculated to facilitate their studies, and render their labor less irksome, by constantly keeping before them definite objects of interest.—*The Lancet.*

BY THE SAME AUTHOR. (*Now Ready*, May, 1857.)

ON DISEASES OF THE SKIN. Fourth and enlarged American, from the last and improved London edition. In one large octavo volume, of 650 pages, extra cloth, $2 75.

This volume in passing for the fourth time through the hands of the author, has received a careful revision, and has been greatly enlarged and improved. About one hundred and fifty pages have been added, including new chapters on Classification, on General Pathology, on General Therapeutics, on Furuncular Eruptions, and on Diseases of the Nails, besides extensive additions throughout the text, wherever they have seemed desirable, either from former omissions or from the progress of science and the increased experience of the author. Appended to the volume will also now be found a collection of SELECTED FORMULÆ, consisting for the most part of prescriptions of which the author has tested the value.

The writings of Wilson, upon diseases of the skin, are by far the most scientific and practical that have ever been presented to the medical world on this subject. The present edition is a great improvement on all its predecessors. To dwell upon all the great merits and high claims of the work before us, *seriatim*, would indeed be an agreeable service; it would be a mental homage which we could freely offer, but we should thus occupy an undue amount of space in this *Journal*. We will, however. look at some of the more salient points with which it abounds, and which make it incomparably superior in excellence to all other treatises on the subject of dermatology. No mere speculative views are allowed a place in this volume, which, without a doubt, will, for a very long period, be acknowledged as the chief standard work on dermatology. The principles of an enlightened and rational therapeia are introduced on every appropriate occasion. The general practitioner and surgeon who, peradventure, may have for years regarded cutaneous maladies as scarcely worthy their attention, because, forsooth, they are not fatal in their tendency; or who, if they have attempted their cure, have followed the blind guidance of empiricism, will almost assuredly be roused to a new and becoming interest in this department of practice, through the inspiring agency of this book.—*Am. Jour. Med. Science*, Oct. 1857.

ALSO, JUST READY,

A SERIES OF PLATES ILLUSTRATING WILSON ON DISEASES OF THE SKIN; consisting of nineteen beautifully executed plates, of which twelve are exquisitely colored, presenting the Normal Anatomy and Pathology of the Skin, and containing accurate representations of about one hundred varieties of disease, most of them the size of nature. Price in cloth $4 25.

In beauty of drawing and accuracy and finish of coloring these plates will be found superior to anything of the kind as yet issued in this country.

The plates by which this edition is accompanied leave nothing to be desired, so far as excellence of delineation and perfect accuracy of illustration are concerned.—*Medico-Chirurgical Review.*

Of these plates it is impossible to speak too highly. The representations of the various forms of cutaneous disease are singularly accurate, and the coloring exceeds almost anything we have met with in point of delicacy and finish.—*British and Foreign Medical Review.*

BY THE SAME AUTHOR.

ON CONSTITUTIONAL AND HEREDITARY SYPHILIS, AND ON SYPHILITIC ERUPTIONS. In one small octavo volume, extra cloth, beautifully printed, with four exquisite colored plates, presenting more than thirty varieties of syphilitic eruptions. $2 25.

BY THE SAME AUTHOR. (*Just Issued.*)

HEALTHY SKIN; A Popular Treatise on the Skin and Hair, their Preservation and Management. Second American, from the fourth London edition. One neat volume, royal 12mo., extra cloth, of about 300 pages, with numerous illustrations. $1 00; paper cover, 75 cents.

WILDE (W. R.),
Surgeon to St. Mark's Ophthalmic and Aural Hospital, Dublin.

AURAL SURGERY, AND THE NATURE AND TREATMENT OF DISEASES OF THE EAR. In one handsome octavo volume, extra cloth, of 476 pages, with illustrations. $2 80.

WEST (CHARLES), M. D.,

Accoucheur to and Lecturer on Midwifery at St. Bartholomew's Hospital, Physician to the Hospital fo Sick Children, &c.

LECTURES ON THE DISEASES OF INFANCY AND CHILDHOOD.

Second American, from the Second and Enlarged London edition. In one volume, octavo, extra cloth, of nearly five hundred pages. $2 00.

We take leave of Dr. West with great respect for his attainments, a due appreciation of his acute powers of observation, and a deep sense of obligation for this valuable contribution to our professional literature. His book is undoubtedly in many respects the best we possess on diseases of children. *Dublin Quarterly Journal of Medical Science.*

Dr. West has placed the profession under deep obligation by this able, thorough, and finished wor upon a subject which almost daily taxes to the u most the skill of the general practitioner. He ha with singular felicity threaded his way through a the tortuous labyrinths of the difficult subject he ha undertaken to elucidate, and has in many of th darkest corners left a light, which will never b extinguished.—*Nashville Medical Journal.*

BY THE SAME AUTHOR. (*Just Issued.*)

LECTURES ON THE DISEASES OF WOMEN. In two parts.

PART I. 8vo. cloth, of about 300 pages, comprising the DISEASES OF THE UTERUS. $1 65.

PART II. (*Preparing*), will contain DISEASES OF THE OVARIES, and of all the parts connecte with the UTERUS; of the BLADDER, VAGINA, AND EXTERNAL ORGANS.

The object of the author in this work is to present a complete but succinct treatise on Femal Diseases, embodying the results of his experience during the last ten years at St. Bartholomew' and the Midwifery Hospitals, as well as in private practice. The characteristics which have se cured to his former works so favorable a reception, cannot fail to render the present volume standard authority on its important subject. To show the general scope of the work, an outline o the Contents of Part I. is subjoined.

Lectures I., II.—INTRODUCTORY—Symptoms—Examination of Symptoms—Modes of Examina tions. *Lectures III., IV., V.*—DISORDERS OF MENSTRUATION, Amenorrhœa, Menorrhagia, Dys menorrhœa. *Lectures VI., VII., VIII.*—INFLAMMATION OF THE UTERUS, Hypertrophy, Acut Inflammation, Chronic Inflammation, Ulceration of the Os Uteri, Cervical Leucorrhœa. *Lectur IX., X., XI., XII., XIII.*—MISPLACEMENT OF THE UTERUS, Prolapsus, Anteversion, Retrover sion, Inversion. *Lectures XIV., XV., XVI., XVII.*—UTERINE TUMORS AND OUTGROWTHS Mucous, Fibro-cellular, and Glandular Polypi, Mucous Cysts, Fibrinous Polypi, Fibrous Tumors Fibrous Polypi, Fatty Tumors, Tubercular Diseases. *Lectures XVIII., XIX., XX.*—CANCE OF THE UTERUS.

PART II. will receive an equally extended treatment, rendering the whole an admirable text-boo for the student, and a reliable work for reference by the practitioner.

BY THE SAME AUTHOR. (*Just Issued*)

AN ENQUIRY INTO THE PATHOLOGICAL IMPORTANCE OF ULCER ATION OF THE OS UTERI. In one neat octavo volume, extra cloth. $1 00.

WILLIAMS (C. J. B.), M. D., F. R. S.,

Professor of Clinical Medicine in University College, London, &c.

PRINCIPLES OF MEDICINE. An Elementary View of the Causes, Nature, Treatment, Diagnosis, and Prognosis of Disease; with brief remarks on Hygienics, or the pre servation of health. A new American, from the third and revised London edition. In one octavo volume, leather, of about 500 pages. $2 50. (*Now Ready*, May, 1857.)

The very recent and thorough revision which this work has enjoyed at the hands of the autho has brought it so completely up to the present state of the subject that in reproducing it no additions have been found necessary. The success which the work has heretofore met shows that its im portance has been appreciated, and in its present form it will be found eminently worthy a continu ance of the same favor, possessing as it does the strongest claims to the attention of the medica student and practitioner, from the admirable manner in which the various inquiries in the different branches of pathology are investigated, combined and generalized by an experienced practical phy sician, and directly applied to the investigation and treatment of disease.

We find that the deeply-interesting matter and style of this book have so far fascinated us, that we have unconsciously hung upon its pages, not too long, indeed, for our own profit, but longer than re viewers can be permitted to indulge. We leave the further analysis to the student and practitioner. Our judgment of the work has already been sufficiently expressed. It is a judgment of almost unqualified praise. The work is not of a controversial, but of a didactic character; and as such we hail it, and recommend it for a text-book, guide, and constant companion to every practitioner and every student who wishes to extricate himself from the well-worn ruts of empiricism, and to base his practice of medi cine upon principles.—*London Lancet*, Dec. 27, 1856.

A text-book to which no other in our language is comparable.—*Charleston Medical Journal.*

No work has ever achieved or maintained a more deserved reputation.—*Va. Med. and Surg. Journal.*

WHITEHEAD ON THE CAUSES AND TREATMENT OF ABORTION AND STERILITY. Second American Edition. In one volume, octavo, extra cloth, pp. 308. $1 75.

YOUATT (WILLIAM), V. S.

THE HORSE. A new edition, with numerous illustrations; together with a general history of the Horse; a Dissertation on the American Trotting Horse; how Trained and Jockeyed; an Account of his Remarkable Performances; and an Essay on the Ass and the Mule. By J. S. SKINNER, formerly Assistant Postmaster-General, and Editor of the Turf Register. One large octavo volume, extra cloth. $1 50.

BY THE SAME AUTHOR.

THE DOG. Edited by E. J. LEWIS, M. D. With numerous and beautiful illustrations. In one very handsome volume, crown 8vo., crimson cloth, gilt. $1 25.